SCIENCE, AERONAUTICS AND TECHNOLOGY

FISCAL YEAR 2000 ESTIMATES

BUDGET SUMMARY

OFFICE OF AERO-SPACE TECHNOLOGY — **AERONAUTICAL RESEARCH & TECHNOLOGY**

SUMMARY OF RESOURCES REQUIREMENTS

	FY 1998	FY 1999	FY 2000	Page Number
	(Thousands of Dollars)			
Research and technology base	428,300	424,100	425,800	SAT 4.1-2
Aeronautical focused programs	491,800	344,800	194,200	SAT 4.1-22
Total	920,100	768,900	620,000	
Distribution of Program Amount by Installation				
Johnson Space Center	669	1,085	0	
Marshall Space Flight Center	2,302	2,428	2,133	
Ames Research Center	229,699	198,040	196,711	
Dryden Flight Research Center	93,425	77,809	91,405	
Langley Research Center	325,008	265,633	163,329	
Glenn Research Center	249,992	206,832	158,235	
Goddard Space Flight Center	5,566	7,244	0	
Jet Propulsion Laboratory	1,387	1,769	0	
Headquarters	12,052	8,060	8,187	
Total	920,100	768,900	620,000	

BASIS OF FY 2000 FUNDING REQUIREMENT

AERONAUTICS RESEARCH AND TECHNOLOGY BASE

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Information Technology	72,800	66,500	90,100
Airframe Systems	140,400	138,500	137,900
Propulsion Systems	72,000	75,400	66,200
Flight Research	82,100	70.600	87,700
Aviation Operations Systems	28,400	43,400	17,000
Rotorcraft	32,600	27,200	26,900
Construction of Facilities		2,500	(10,700)*
Total	428,300	421,600	425,800

*Program Direct Construction of Facilities funds in FY 2000 included within other R&T Base elements.

PROGRAM GOALS

The goal for NASA's Aeronautics Research and Technology (R&T) Base is to serve as the vital foundation of expertise and facilities that consistently meets a wide range of aeronautical technology challenges for the nation. The R&T Base is intended to provide a high-technology, diverse-discipline environment that enables the development of new, even revolutionary, aerospace concepts and methodologies for applications in industry. Each program of the R&T Base has an objective to develop multidisciplinary methods and technology that contributes to one or more of the Aero-Space Technology Enterprise goals. In particular, the initial $500M commitment over five years of the Enterprise to achieve the goals of the Administration’s Aviation Safety Initiative was initially supported from reinvestments made within the R&T Base. Work within the R&T Base lays the foundation for future focused programs to address the long term goals of the enterprise’s Three Pillars. This work constitutes a national resource of expertise and facilities that responds quickly to critical issues in safety, security, and the environment. These same technological resources contribute to the overall U. S. defense and non-defense product design and development capabilities.

STRATEGY FOR ACHIEVING GOALS

The technology environment for success in aerospace is characterized by continuous advances across a wide range of disciplines, as well as developments of revolutionary technology. With the downsizing of research facilities and basic research capabilities in industry and government agencies, the R&T Base is critical in the continual struggle for technological preeminence in the world-wide aerospace scene. Through basic and applied research in partnership with industry, academia, and other government agencies, NASA develops critical high-risk technologies and advanced concepts for U. S. aircraft and engine industries. These advanced concepts and technologies allow a safe, highly productive global air transportation system that includes a new generation of environmentally compatible, economical U. S. aircraft that are competitive in the marketplace.

The R&T Base is an essential element of the Enterprise, for it is here that new technologies that lead to future advanced aerospace products are conceived. Providing a strong foundation for the fundamental understanding of a broad range of physical phenomena, development of computational methods to analyze and predict physical phenomena, and experimental validation of key analytical capabilities. The R&T Base also develops revolutionary concepts, highly advanced, accurate computational tools and breakthrough technologies that can reduce the development time and risk of advanced aerospace systems and high performance aircraft. A significant portion of the research and concept development in the R&T Base is performed through partnerships and cooperative agreements with the aerospace industry and other government agencies to facilitate rapid technology transfer. Also, the R&T Base supports the vast majority of the Enterprise's peer-reviewed fundamental research with academia and industry. The program also provides the capability for NASA to respond quickly and effectively to critical problems identified by other agencies, industry or the public. Examples of these challenges are found in: aircraft accident investigations, lightning effects on avionics, flight safety and security, wind shear, crew fatigue, structural fatigue, and aircraft stall/spin.

One of the key factors in aeronautical research is an extensive use of research facilities that are located at the four aeronautical research centers: 1) Ames Research Center, 2) Dryden Flight Research Center, 3) Langley Research Center, and 4) Glenn Research Center. Many facilities, such as the National Transonic Facility, the National Full-Scale Aerodynamics Complex, the Icing Research Tunnel and the fleet of research aircraft are unique in the U. S. and even the world. Other factors underpinning continued governmental support of aeronautical research include: the public-good character of much of the research (safety, environment, certification, national security); large disincentives for private sector investment in long term, high risk aeronautical R&T, since an individual company can rarely capture the full benefit; the length of time for the aircraft research-and-development cycle and the total investment recoupment period; the extensive breadth and depth of technologies required to produce a superior aircraft; and the unique cadre of experienced NASA technical personnel.

The Aeronautics R&T is a framework of six systems oriented, customer driven programs, that serve the needs of the full range of aeronautical vehicle classes. The six R&T Base programs are:

1. Information Technology: The primary focus of this program is on the development of computational tools and integrated systems for the design and manufacture of flight vehicles and systems.

2. Airframe Systems: The Airframe systems technologies have application to all flight vehicles that operate in the atmosphere with emphasis in areas such as: conceptual design; aerodynamic and structural design and development; flight crew station design; and airborne systems design and testing.

3. Propulsion Systems: The purpose of this program is to design and develop efficient, safe, affordable and environmentally compatible propulsion system technologies for subsonic and high speed transports, general aviation and high performance aircraft.

4. Flight Research: The technology development under this program is aimed at remotely piloted aircraft, high performance aircraft, hypersonics, and tools and test techniques

5. Aviation Operation Systems (AOS): The AOS program is structured to address critical technologies in communications, navigation and surveillance systems, air traffic management, relevant cockpit systems, operational human factors, and weather and hazardous environment characterization and avoidance systems.

6. Rotorcraft: The rotorcraft program meets the challenge of technology leadership by developing: technology for improved flight safety; technology for reduced noise for passengers and the community; and design tools for reduced design-cycle time and reduced manufacturing costs.

Additionally, the R&T Base includes facilities that directly support Aeronautical research.

Accomplishments over the past year continue to provide a foundation for longer term technology development to address national needs as outlined in the Enterprise’s Three Pillars for Success, and to provide research facilities operations and expert consultation for industry during their product development design and build processes. Conceptual studies took into consideration various state-of-the-art technologies to reduce aircraft design and manufacturing costs and addressed breakthrough technology requirements for future commercial and general aviation transports, rotorcraft, hypersonic vehicles, as well as high performance and high altitude remotely piloted aircraft. The R&T Base continues to sponsor and conduct research using cooperative programs, not only to leverage resources for technology development, but also to ensure timely technology transfers to U. S. customers.

SCHEDULE AND OUTPUTS

Information Technology

Acquire and install High Speed Processor 4. Plan: September 1998 Actual: September 1998	Delivered to Numerical Aerodynamics Simulation (NAS) community a demonstrated capability of a symmetric multi-processor to deliver scaleable performance at less than 25% of the cost of High Speed Processor (HSP) 3.
Demonstrate knowledge system prototype in test facility. Plan: September 1998 Actual: September 1998	Demonstrated reduction in design cycle time by the application of intelligent information analysis and unified instrumentation.

Adaptive coefficient based controller flight demonstrated in shadow mode on the F-15 ACTIVE aircraft. Plan: December 1998 Revised: March 1999	Achieve neural net reconfiguration in flight. Milestone slip due to projected late availability of flight test vehicle.
Demonstrate prototype heterogeneous distributed computing environment Plan: September 2000	Demonstrate tools and software to link distributed computing test-beds at multiple NASA Centers into a single “virtual” supercomputing environment.
Demonstrate real-time aerospace design exploration Plan: September 2000	Demonstrate real-time access to computational simulations, experimental data sources and archived data for aerospace design exploration.

Airframe Systems

Complete flow physics data for 2-D high-lift methods Plan: September 1998 Actual: September1998	Benchmarked data-set acquired for validation of CFD codes
Complete Mach 7 Research Vehicle tests in LaRC’s 8-foot High-Temperature Tunnel. Plan: March 1998 Actual: June 1998	Completed system check-out in Mach-7, flight-type environment and obtained ground based data for direct comparison with flight.
Verify Electromagnetic Emissions (EME) immunity procedures to emulate specific aircraft EME environment. Plan: September 1998 Actual: September 1998	Completed High Intensity Radiated Fields (HIRF) Laboratory tests to verify EME immunity procedures. Test procedures developed and presented to RTCA, Inc. and FAA Electromagnetic Committees.
Develop technologies for smart	Implementation of active control for 20 percent increase in airfoil maximum lift coefficient.

aircraft systems to provide cost-effective improvements in boundary layer control. Plan: September 1999	
Mach 7 Research Vehicle Flight. Plan: January 2000	Successfully accomplish research objectives of the dual mode scramjet powered flight tests.
Flight Validation of Falling Leaf criterion Plan: March 2000	Flight Validated design tool for predicting and avoiding loss of control (Falling Leaf) in high performance aircraft
Full-scale shape memory alloy (SMA) nozzle control demonstrated Plan: September 2000	Demonstrated feasibility of full scale SMA nozzle at simulated operating loads
10 dB community noise impact reduction. Plan: September 2000	Subscale validation of technology to reduce community noise impact by 10 dB relative to 1992 technology. High fidelity engine simulator tests in wind tunnels will be used to demonstrate 6 dB engine noise reduction and 50 percent nacelle liner improvement. Similarly, flap, slat and gear airframe noise reductions resulting in a 4 dB total airplane airframe noise reduction will be demonstrated in model-scale wind tunnel tests.
Validate affordable General Aviation avionics system architecture. Plan: September 2000	Validate COTS-based technology for affordable, highly integrated, open architecture, modular avionics system for Highway in the Sky graphical operating capability.

Propulsion Systems

Complete engine fabrication for advanced general aviation turbine and intermittent combustion engines. Plan: September 1998 <u>IC Engine</u> Actual: September 1998 <u>Turbine Engine</u> Actual: December 1998	Complete fabrication in time to meet FY 2000 flight test schedules. Intermittent Combustion Engine: First engine assembled and tested. Turbine Engine: First build of all major components rig tested. Completing fabrication of the first turbine engine slipped due to a turbine component manufacturing error. A second turbine component was manufactured successfully and the engine was successfully assembled in December. This slip will have no impact on future milestones.
Provide materials and processing for turbine inlet temperatures above 2,400° F. Plan: June 1999	CMC specimen with cooling holes successfully survives burner test.
Complete engine pre flight ground tests for GAP engines. Plan: September 1999	Complete altitude test of the turbine engine and the sea level test of intermittent combustion engine at NASA test facilities.
Complete flight demonstration of GAP engines. Plan: September 2000	Flight demonstrate the intermittent combustion engine and the turbine engine at Oshkosh Air Show.
Demonstrate 900°F SiC sensor on an engine. Plan: September 2000	Commercial grade, high temperature sensor demonstrated at 900°F.
Demonstrate ‘smart’ turbomachinery concepts to minimize pollutants throughout mission cycle. Plan: September 2000	Active combustion control strategy rig demonstrated; 20dB suppression of instability driven acoustic energy.

Flight Research

Complete X-36 flight evaluation.	Complete flight objectives and analysis of vehicle performance.
Plan: June 1997 Actual: December 1997	Delay was due to the systems and software development for the flight vehicle. Highly successful flight evaluation achieved all program objectives. Measured performance exceeded predictions. Provides credible database for tailless fighters of the future.
Flight-demonstrate an inlet-distortion-tolerant control system.	Evaluate in flight, on the Advanced Control Technology Integrated Vehicle (ACTIVE) aircraft, a high-stability, integrated control system using sensed inlet distortion to enhance stability.
Plan: September 1998 Actual: June 1998	Data analysis of data demonstrated increased engine stability through the high stability integrated control system using sensed inlet distortion.
Complete piston-powered turbocharged RPA flight for 8 hours at 60,000 feet.	As part of ERAST demonstrate record-breaking high-altitude duration capability to validate the capability for science missions of greater than 4 hours duration in remote deployments to areas such as the polar regions above 55,000 feet.
Plan: September 1998 Revised: March 1999	Delayed due to lubrication and cooling system problems
Complete significant advance in flight visualization measurement techniques.	Flight evaluation of flight measurement and test techniques including in-flight Schlieron imaging system and in-flight infrared transition detection system.
Plan: September 1999	
Flight demonstrate dropping-of-windsonde compatibility with RPA at altitudes above 55,000 feet.	Demonstrate the utility of carrying and delivering miniaturized windsondes (wind measuring sensors) to obtain meteorological data with the Altus Remotely Piloted Airplane up to 55,000 foot altitude.
Plan: September 1999 Actual: Deleted	Deleted due to ERAST re-planning to better develop technology for operational vehicles to meet the science community needs.
Complete low altitude flights of Centurion Plan: January 1999	Demonstrate systems functionality of remotely piloted aircraft with wingspan greater than 200 feet, suitable for flight to 100,000 feet in altitude once outfitted with high performance solar cells.
Demonstrate 2 aircraft formation flight utilizing autonomous station-keeping controls	Demonstrate functionality of autonomous station keeping on two F-18's in support of establishing practical operability of precision formation flight for drag reduction and consequently reduce fuel burn.

Plan: January 2000	
Complete low-altitude flight of Helios Plan: March 2000	Demonstrate a solar-powered remotely piloted aircraft with wingspan greater than 250 feet suitable for flight to 100,000 feet in altitude or a duration of 100 hours once outfitted with high performance solar cells
Complete assessment of science mission demonstration Plan: September 2000	Complete assessment of remotely piloted aircraft science mission capability based on experience from two or more platform configurations applied to different mission requirements and science sensors independently selected by user community.

Aviation Operations Systems

Complete icing-tunnel database of ice shapes for modern airfoils. Plan: June 1998 Actual: August 1998	Completed tests in Glenn Research Center Icing Research Tunnel. Identified key two-dimensional ice shapes for modern airfoils. Leading-edge models were provided for aerodynamic wind-tunnel testing at Langley Research Center.
Complete flight tests and instrumentation comparison for the NASA/AES Joint Super-cooled Large Droplet (SLD) icing program. Plan: June 1999	Develop SLD icing research data acquisition and processing methods through joint SLD flight operations and collaborative instrumentation development with the Canadian agency.
Develop the model of human memory constraints in reactive planning and procedure execution. Plan: September 1999	Demonstrate, using full mission simulation, safety benefits of automation design using models of human memory.
Define framework for cost-benefit model consistent with NAS and human performance. Plan: September 2000	Define overall framework for cost-benefit model integrating (National Airspace System (NAS) and human performance models.
Conduct representative safety analysis for air-ground automation and operational	Conduct a representative safety analysis for air-ground automation and operational procedures to validate a theory-based methodology for predicting operational error-vulnerability.

procedures.

Plan: July 2000

Rotorcraft

Validate advanced computational methods for the prediction of rotor/airframe interaction and unsteady aerodynamics with data acquired from advanced laser velocimetry techniques. Plan: January 1998 Corrected: January 1999 Revised: March 2002	Assess the accuracy of unsteady computational aerodynamic predictions of rotor/fuselage aerodynamic interference, based on validation using advanced, non-intrusive, three-dimensional flow measurements. Milestone date was incorrectly reported in FY 1999 narrative. During that initial test entry, significant difficulties were encountered with acquiring the unsteady Doppler Global Velocimetry (DGV) (first time that unsteady DGV had ever been attempted in a wind tunnel). As a result of extreme demand on the facility (14- by 22-Foot Subsonic Tunnel) and two scheduled shutdowns of that facility for upgrades, it is unlikely that the next attempt to acquire unsteady DGV data on a rotor in forward flight will occur before 3rd quarter FY01. Therefore, the completion of the milestone was rescheduled for 2nd quarter FY02.
Demonstrate Master Cure Simulation System (MCSS) for manufacturing thick-composite rotorcraft structures. Plan: September 1998 Revised: June 1999	Under National Rotorcraft Technology Center (NRTC), validate and demonstrate that master cure process molding and controller accurately predict/control thick-composite-material behavior and its rate of cure. Additional testing required to refine processes; fabrication of demonstration component rescheduled to reduce costs.
Demonstrate high-quality, low-cost composite manufacturing of critical rotorcraft components using resin transfer molding process. Plan: September 1999	Improve cost and reliability of components using resin transfer molding process for actual hardware.

Validate prediction of main rotor noise as measured during flight tests, by comparison of measured helicopter footprints with predictions. Plan: September 1999	Provide flight validated computational codes for the prediction of helicopter noise footprints.
Flight demonstrate active control technology for rotorcraft interior noise reduction; provide interior noise prediction methods for a range of rotorcraft types. Plan: December 1999	Validated technology for interior low noise design.
Flight validate advanced control laws/modes for reduced pilot workload and increased safety in low visibility using integrated design tool (CONDUIT). Plan: March 2000	Demonstrate industry confidence in CONDUIT as a low cost control law development and optimization tool.

ACCOMPLISHMENTS AND PLANS

Information Technology

In FY 1998, the Information Technology program developed a knowledge-based design system prototype and demonstrated the technology in a wind tunnel test environment. This system acquired data from experiments and numerical simulations, rapidly analyzed the data and provided advisories to design engineers regarding the results and opportunities for design improvements. This system allowed engineers to redesign a flap element of a subsonic transport high-lift system and to retest the newly designed component during the same wind tunnel test entry. The ability to save a cycle of wind tunnel testing required for preliminary design and the potential to significantly reduce design cycle time has been demonstrated. Also completed in FY98 is an intelligent flight control system. In collaboration with The Boeing Company, the newly-developed system is a major step forward in demonstrating the potential to regain safe, controllable flight characteristics after a major change such as a damaged wing, greatly increasing the chances for survival and safe return under such circumstances. The intelligent flight control system will be flight tested on board an F-15 flight research aircraft at the beginning of FY 1999. A communication system for the aviation community is being developed that will enable aviation safety information to be accessed, analyzed, and disseminated rapidly throughout the National Airspace System, helping to reveal current risk factors, identify emerging trends, and address the most important issues in aviation safety. Key connections with operational ground facilities and airlines for real-time aircraft performance data have been completed. A new high-speed processor, HSP-4, has been obtained and integrated into the aeronautics supercomputing system. This machine has demonstrated sustained processing speeds of 20 GFLOPS (billion floating-point operations per second) for realistic aerospace design and analysis problems with highly favorable price-to-performance metrics. Tools and techniques to generate safe software automatically for complex, flight-critical systems at greatly reduced time and cost continue to be developed, as well as the means to protect and verify the integrity of data communications within the aviation system.

In FY 1999, the Information Technology program will further develop integrated design techniques, including wind tunnel flow quality and testing productivity enhancements, more accurate model positioning and balance calibration systems, on-line real-time test data and more versatile user interfaces. Of particular focus within the integrated design effort will be to transition the technology from aircraft to space transportation systems. Specifically, the integrated design tools will be adapted and applied to thermal protection system design of reusable launch vehicles. Together with advanced instruments and data acquisition systems, this effort will continue the development of capabilities for real-time design exploration of aerospace vehicles. An intelligent, neural-network flight control system will be flown on an F-15 research aircraft, and work will be initiated to integrate this capability with propulsion control, health monitoring and diagnosis capabilities. Intelligent tools for an aviation safety data sharing network will be developed and a prototype data sharing network will be established. An effort to demonstrate real-time data sharing with a flight vehicle is planned. Next-generation computing systems will be developed that take advantage of geographically distributed resources, requiring new capabilities in network quality of service, data storage, retrieval and analysis, and system operations including scheduling, planning, and accounting. Software technology developments will contribute to enhancing the reliability of complex, flight-critical systems (such as flight control systems), and reducing the cost of producing, verifying, and validating these systems. Tools for ensuring and verifying the integrity of wireless data communications will be developed and demonstrated to enhance the safety of the future National Airspace System.

In FY 2000, the Information Technology program will complete a demonstration of real-time aerospace design exploration. The developed environment will include remote connectivity, access to experimental data in real-time, capability to perform simulations in near-real-time, and access to databases with analysis tools to support design. All of these capabilities will be coupled with newly-developed instrumentation and data systems to provide previously unavailable experimental data. In addition to reductions in access time to high-fidelity simulations data, specific goals of the system include a reduction in access time to experimental data by a factor of five, and a reduction in access time to archived database sources by a factor of two. Improvements in software technology will result in the development of verifiably-correct program synthesis technology. Tools will be demonstrated to reduce time in software coding and testing. Specifically targeted applications will demonstrate these tools on real-world, complex software development activities meeting NASA mission requirements. Finally, the first prototype of a geographically-distributed heterogeneous high-end computing system will be developed and demonstrated for NASA supercomputing requirements. The developed software tools will link multiple NASA supercomputing assets seamlessly and transparently to the end-users. The overall computing capability enabled by this technology will allow for geographically dispersed engineering collaboration and greater peak computing power. The Information Technology program also includes Intelligent Synthesis Environment (ISE), which will revolutionize the way aircraft and space transportation vehicles are designed by providing new modeling tools and methods to enable rapid in-depth computation of system life-cycles in a networked environment. The ISE efforts will be focused in two specific areas: (1) collaborative engineering environments (CEE) and (2) rapid synthesis and simulation tools (RSST). In CEE, geographically distributed collaborative teams will apply user-ready, state-of-the-art tools to life-cycle assessments of Enterprise-focused mission applications and will develop advanced engineering processes that will be able to exploit advanced design and analysis tools. In RSST, activities will be initiated to provide new modeling tools and methods for engineering and science systems, to enable rapid in-depth computation of system life-cycles in a networked environment.

Airframe Systems

In FY 1998, the **Airframe Systems** program developed technology in the areas of safety, environmental compatibility, affordable air travel, next-generation design tools and experimental aircraft. A top-down conceptual error-proof flight deck design with traceability to human-centered design guidelines and philosophy was completed. Tests in wind tunnels have been conducted to model the aerodynamic forces mathematically to produce realistic simulations for future simulators which are a valuable tool for pilot training. A reverse geometry x-ray system was developed for detection and quantification of corrosion in aircraft structure. To enhance environmental compatibility of aircraft, studies were completed on active control of jet noise emissions for reduced community noise. Surface shape change and doublet device modeling concepts were formulated leading to a control system that is effective for aircraft utilizing novel aerodynamic flow control actuators. A method was also developed to find optimized piezoelectric actuator locations for active structural acoustic control. Key technology barriers for future subsonic transports were addressed including advanced vehicle configurations such as the Blended Wing Body (BWB). Successful tests of the BWB configuration were completed. Cost and performance benefit over conventional configuration show this aircraft concept has improved lift-to-drag and reduced fuel burn and takeoff weight. Performance assessment of machined and extruded integrally stiffened curve fuselage panels was completed for possible reduction of aircraft weight and cost with no loss in durability or damage tolerance. Crack turning was incorporated into a finite element model. A series of experiments were completed to develop turbulence models to accurately predict detailed characteristics of turbulence vortex breakdown flows. To provide a validation database and to better understand the fundamental flow physics associated with high-lift systems, detailed measurements for transition and Reynolds stress profiles were obtained. Transition modeling, which was not incorporated into computational fluid dynamics (CFD) codes, was integrated with turbulence modeling for high-lift flows. Order of magnitude decreases in design cycle time are occurring through aerodynamic and finite element method code integration. Airframe Systems continued assistance in solving technical problem with existing aircraft. A breadboard buffet alleviation system has been developed and experimentally tested which indicates an order of magnitude improvement to the vertical tail fatigue life. A flight recovery technique was developed in simulation for the out-of-control “Falling Leaf “ phenomenon. NASA expertise is being utilized in the development of the Joint Strike Fighter via experimental test results. The first Hyper-X research vehicle (HXRV) and launch vehicle have passed critical design reviews. Most of the HXRV structure has been fabricated and assembled, and the launch vehicle rocket motor delivered. Preflight testing of aerodynamic, propulsion and stage separation continued throughout the year. Preparations were nearly complete for a full flowpath test of the flight engine mated to a full-scale wind tunnel model of the HXRV. In FY 1999, the Airframe Systems program will develop technology in safety including complete simulations of crew workload displays. This will be used to help reduce accidents caused by human errors in the flight deck. Nondestructive evaluation techniques will be developed for improvement in crack detection in thick structures by a factor of two. To enhance environmental compatibility, breakthrough technologies in active structural control that allow for significant reduction in aircraft bending loads will be developed. The Airframe Systems Program will address key technology barriers for future subsonic transports. This includes developing aircraft controller strategies for enhancing performance and reconfiguration capabilities. Wind tunnel tests will be conducted to understand the flow physics and the characterization of abrupt wing stall, an uncommanded, abrupt roll perturbation during elevated load factor turns. Validated design criteria to address the out-of-control “falling-leaf” phenomenon associated with fighter aircraft will be provided. The Hyper-X Program will continue to support the goals of the Access-to-Space Pillar. Test will begin on the full-scale model of the HXRV. Comparison of CFD performance prediction and correlation with wind tunnel data will also begin.

In FY 2000, the Airframe Systems program will continue to develop technology in the areas of safety, environmental compatibility, affordable air travel, next-generation design tools and experimental aircraft. Comprehensive systems level assessment approach for evaluating the effects of electromagnetic disturbances on critical control computers, and electromagnetic environment (EME) immune flight critical systems will be designed. To enhance environmental compatibility, technologies will be developed to reduce emissions and drag using smart devices with active components. High-payoff, innovative control concepts will be developed and demonstrated. The BWB drop model test will be completed. Conceptual designs of two advanced configuration aircraft will be completed. High-fidelity multi-disciplinary methods for nonlinear problems will be demonstrated. A method to assess the priorities of the Research and Technology projects and to quantify cost of basic research will be delivered. The first flight test of the HXRV will be completed. Also a large-scale airframe noise experiment will be conducted to validate noise reduction concepts. Overall program objectives of 6 dB engine noise reduction, 50 percent liner improvement, 4 dB airframe noise reduction, and 6 dB interior noise reduction, all relative to 1992 production technology, will be confirmed through validated system analysis tools. An affordable general aviation integrated avionics system will be validated and work will continue on the development of a “highway-in-the-sky” operating capability for demonstration in 2001. Manufacturing methods for the new generation of advanced general aviation aircraft, additional training modules in the flight training curricula, the multifunction display guidelines, a low-cost communications, navigation and surveillance system, and a highly integrated open architecture avionics will be completed.

Propulsion Systems

The Propulsion Systems program develops technology that supports all Three Pillars for Success. In FY 1998, the General Aviation Propulsion project focused on fabrication and component tests for the intermittent-combustion and turbine engines scheduled for flight demonstrations in FY 2000. Among other activities, there was a validation of integrated design and process technologies for forged components, permitting a potential 50% reduction in development time and cost. Validated turbine cooling passage computation methods for design of turbines with reduced cooling flow requirements were also developed. The emissions goal is being addressed by the initiation of active combustion instability control effort, and by initial demonstration of better than 70% reduction in NO_x with wall-injection Lean Direct Injection concept. Progress was made toward the goal of increasing turbine inlet temperatures above 2400°F by developing a laminated object manufacturing process, and a method for producing cooling channels. In preparation for a demonstration of 900°F silicon carbide sensor on an engine in FY 2000, there was a demonstration of silicon carbide integrated circuit operation at 1100°F. Some critical component concepts were defined for hybrid propulsion systems capable of hypersonic flight. The High Performance Aircraft sub-element continues active technology validation activities in coordination with DoD. A new project was initiated to improve engine safety by reducing engine component failure to an absolute minimum and containing all possible fragments if an unexpected failure does occur.

During FY 1999, the General Aviation Propulsion project will conduct pre-flight ground tests of the intermittent-combustion and turbine engines in preparation for flight demonstrations in FY 2000. Among other activities, advanced material and process systems capable of turbine inlet material temperatures above 2400°F will be demonstrated. Work will continue on the development of 900°F silicon carbide sensors models, and concepts will be delivered that enable reductions in cost and risk barriers for selected advanced turbine engine components. The High Performance Aircraft project will continue active technology validation activities in coordination with DoD. There will be an effort toward developing critical air-breathing launch vehicle component technology scheduled for validation in FY2000. The effort to improve engine safety also continues with emphasis on development of more crack resistant alloys for blades and disks, and improved containment system.

During FY 2000, the General Aviation Propulsion project will conduct flight demonstrations of the intermittent-combustion engine and the turbine engine at the Oshkosh Air-show. These flights will demonstrate a new generation of general aviation propulsion systems that are revolutionary in affordability, ease of use, and performance. These new engines, with their smooth, quiet operation, promise to be the key to creating new demand for aircraft and revitalizing the U.S. general aviation industry. Among other activities, there will also be a demonstration of a 900°F silicon carbide sensor on an engine. This demonstration is a daring leap from laboratory development of SiC pressure sensor and electronics into a real application in the harsh engine environment, that could, if successful, lead to sensor development for many commercial and military applications. Active combustion instability control will form the cornerstone of demonstrating "smart" turbomachinery concepts to minimize pollutants throughout a typical mission. The technology that will be rig demonstrated, a 20dB suppression of instability driven acoustic energy, is a critical enabling technology for stable operations under lean combustion conditions that can potentially lead to as much as 80% No_x reduction in the future. Validation ground testing of air-breathing launch vehicle critical component technology is planned, along with the development of an air-breathing launch vehicle reference vehicle concept. The effort to improve engine safety will continue to seek alloys for blades and disks which are more crack resistant for delivery in FY 2001, while a subscale containment system will be evaluated this year. The High Performance Aircraft project will continue active technology validation activities in coordination with DoD.

Flight Research

In FY 1998 the Flight Research program, under the environment goal, accomplished a significant achievement with the highlight coming with a world-record breaking flight of the solar-powered Pathfinder Plus Remotely Powered Airplane (RPA) to an altitude of 80,200 feet. This RPA technology will increase the Nation's capability to make scientific sampling high in the atmosphere. In pursuit of improved aviation safety, a new effort began to help transition technology into use by the air transportation industry. This technology will be drawn from the other program elements, and make use of testbed aircraft to raise the technology readiness level. In pursuit of efficiency and affordability, the Systems Research Aircraft completed the Electrically Powered Actuator Development Flight experiments activity, which includes several types of electrical actuators. In pursuit of improved US aircraft and engine performance, within the Integrated Controls area, the Advanced Control Technologies for Integrated Vehicles completed the characterization of the axisymetric thrust vectoring. The ground testing of the closed loop mult-iaxis vectoring nozzles, coupled through a fully integrated interloop flight control system was also completed. In pursuit of high-speed travel, US pilot handling quality evaluations of the Tu-144 were completed. Under an advanced concept activity, several efforts are underway. In an international cooperative program, a scramjet built by the Russian Central Institute of Aviation Motors completed its flight test, providing pristine data on the transition from subsonic (ramjet) to supersonic (scramjet) modes..

During FY 1999, the Flight Research program continues to develop concepts through ERAST, including the demonstration of multistage turbocharged RPA to 60,000 feet for an 8 hour duration. Also, flights will continue with the Centurion solar-powered airplane which will be designed to eventually reach 100,000 feet altitude. This RPA technology will increase the Nation's capability to make scientific sampling high in the atmosphere. In pursuit of improved aviation safety, the effort to help transition technology into use by the air transportation industry will completed. This technology will be drawn from the other program elements, and make use of testbed aircraft to raise the technology readiness level. In pursuit of efficiency and affordability, an F-

18 testbed aircraft will be modified to investigate Active Aeroelastic Wing (AAW) technology in preparation for the flight tests, which will begin in FY 2000. In support of the efficiency and affordability goal, the flight assessment of the advanced actuators flight experiment using the F-18 Systems Research Aircraft will be completed. Under advanced concepts, the PHYSX test program, a Pegasus launch vehicle with a wing glove fixture measured the cross-flow boundary layer at hypersonic (Mach 8) speed, providing critical design data for vehicles that will provide access to space. The flight experiment was flown in November 1998 and was completely successful. In the continuing effort to improve flight research tools and test techniques, a significant advance in flight visualization measurement techniques is planned to be fully demonstrated in flight.

The Flight Research program in FY 2000 will be developing further capability for increased altitude using ERAST remotely piloted airplanes (RPA). The Centurion solar-powered RPA designed for flight to 100,000 feet will be modified to a longer wingspan configuration, named Helios. This configuration will be more suitable for extreme endurance as well as short flights to the 100,000 ft. altitude. It will be demonstrated ready for later upgrade to high-efficiency solar cells and the maximum altitude missions. In pursuit of efficiency and affordability, an F-18 testbed aircraft will have been modified to investigate Active Aeroelastic Wing (AAW) technology and completed its first flight. A new effort will be initiated under the X-plane goal, but with applicability to a number of the other goals. Under the name revolutionary concepts, or REVCON, the design and development of a blended wing body sub-scale X-plane will be initiated. This X-plane will be dropped at high altitude from under the wing of the B-52, with the objective of obtaining flight test data on the transonic characteristics of the revolutionary concept. With the first flight in 2001, the new shape is expected to offer major contributions to the goals of increased capacity, reduced emissions, increased throughput and increase mobility. Under the reduced emissions goal, the advanced flight concepts will explore use of precision formation flight in order to reduce overall drag, and consequently reduce fuel burn. The concept will be demonstrated with two F-18 aircraft and automated formation flight system. In the continuing effort to improve flight research tools and test techniques, a significant advance in in-flight sensors for propulsion, aerodynamics and structure-related measurements are planned to be fully demonstrated in flight.

Aviation Operations Systems

In 1998, an icing condition called “Super-cooled Large Droplets” (SLD) was characterized by flight tests. This flight data provides the first measurement of actual sizes and numbers of droplets in natural SLD icing conditions. In partnership with FAA and industry, NASA demonstrated the capability to use airborne lasers for all-weather turbulence detection including a flight evaluation in Juneau, Alaska. The capabilities of the Advanced Performance Measurement system for routinely converting flight-recorded data into information has been declared operational at one airline and successfully demonstrated at a second airline involving a larger fleet of more modern aircraft. A new model-based evaluation methodology that enables prediction of vulnerability of human-automation systems to human error was developed.

During FY 1999, the Aviation Operations System program was re-planned to respond to the President’s safety goal of reducing aviation accidents by 5 fold in 10 years. A model of human memory constraints in procedure execution and reactive planning will be developed. This model will be used to guide design of automation to aid air traffic service providers, airline operations center personnel and flight crews to assure automation support consistent with human performance characteristics. Working with industry, the program will continue to improve the effectiveness of ice protection systems and reduced development and certification cycle & costs for industry. International collaboration, needed for dramatic improvements in aviation safety, will be strengthened by a joint Super-cooled Large Droplet (SLD) icing research conducted with AES (Atmospheric Environment Sciences) of Canada. To enhance safety, an increased emphasis is being put on the development of procedures and innovations to clarify the roles and responsibilities of aircraft maintenance teams. In addition, to reduce weather related accidents, systems for communicating and displaying real time weather information to airborne and ground base users will be pursued in collaboration with industry and DoD, FAA and NOAA/NWS. Initial flight tests will be conducted.

During 2000, the Aviation Operations System program will continue its focus on developing more basic concepts, procedures and systems to remove the key barriers to significant improvements to the safety of the nation's aviation system. A new project to develop a cost/benefit model to analyze new technologies including the effects of human performance will be developed. It will uniquely focus on integrating systems and human performance modeling, and will develop a modeling framework. Fundamental modeling of human performance will incorporate visual motion and eye movement parameters in computational models of human vision. Automation system functional model decomposition methods are being matched to human performance constraints and biases. The result is a theory-based methodology for predicting operational error-vulnerability. This method will be empirically validated through a representative safety analysis for air-ground automation and operational procedures. Ultimately this will result in a computational model matching human/system performance and error trends.

Rotorcraft

During FY 1998 the Rotorcraft program completed the development of rotor wake measurements systems and conducted measurements of rotor/fuselage interaction aerodynamic conditions for future validation of mathematical modules. A composite structures mathematical model was developed and experiments were conducted to validate prediction of fatigue life of thick composite structures. This work increased design accuracy and reduced the number of design iterations contributing to the goal of reduced design cost and time. This effort will contribute towards the goal of a 25% reduction in air travel costs, and reduced design cycle time. Tiltrotor wind tunnel tests continued for active control of aeroacoustics and performed work on active/passive noise and vibration reduction design techniques for conventional helicopters and tiltrotors. Supporting the aviation safety goals, improved performance with the use of drivetrain torque limit cueing provided by force feedback, based on neural network models derived from HUMS, was demonstrated in simulated flight. The results of this successful test were transitioned to the U.S. Army, the FAA, manufacturers, and logging operators. As a step toward making a flight-validated control-system design tool (CONDUIT) available to industry, Cooperative Research and Development Agreements (CRDAs) were established with 10 companies and a short course was offered that covered handling qualities, flight control, and modeling topics associated with the CONDUIT environment. Several analyses of the causes, consequences, and costs of helicopter accidents were completed: (1) a statistical analysis of "first events" codes in the NTSB database for the past 33 years; (2) a more detailed analysis of 1990-1996 accident causes and estimated costs; and (3) an in depth analysis of 34 representative fatal accidents performed by a government/industry team.

The latter identified the chain of events, problems, and suggested technology, procedural, training, and regulatory interventions that might prevent similar accidents in the future. These analyses resulted in a government/industry workshop focused on research areas likely have near-term payoff (e.g., improved training methods and materials and PC-based pre-flight planning and risk assessment systems) and will guide future safety investment decisions. In rotorcraft transmissions, the effect on life-limited components was evaluated using HUMS data from 1996 Olympics missions. The analysis demonstrated that usage tracking of life-limited components could lead to reduced operating costs and that certification data should be based on more maneuvers to improve flight condition recognition algorithms required for HUMS. In support of the overall goal of providing guidelines about crack propagation to support ultra-safe gear design, the effect of rim thickness on gear crack propagation path was investigated using finite element analysis, boundary element analysis, and fracture mechanics. This first phase validated the two-dimensional finite element/fracture mechanics crack-prediction capabilities. The National Rotorcraft Technology Center (NRTC) continues to concentrate on nearer-term needs and has applied 50-50 sharing of investments by industry and the U.S. Government (NASA and DOD) to develop rotorcraft technology ranging from rotor-noise reduction to ultra-safe transmissions. Other examples of responses to industry-wide needs included validated methods for science/computer-based design and cure control for thick composite structure. NRTC continued to further facilitate the design process through a cost-benefits algorithm developed with a newly available rotorcraft health-monitoring database.

In FY 1999, the Rotorcraft program will integrate new basic physics knowledge with advanced, information technology tools to provide accurate, flexible modules suitable for use by industry in their integrated design systems. A new emphasis aimed at thick composite structures will be undertaken to reduce parts count and the cost of rotorcraft. Noise reduction will encompass three areas: more effective noise reduction technologies for the rotor, both passive and active; additional attention to the active reduction of powertrain noise and vibration; and the continued assessment of operations that minimize noise impact on the ground, including the development of codes that can be used by community planners and airport operators. New innovative rotorcraft flight concepts will be actively supported through technical cooperation with DOD and industry. Testing of baseline rotorcraft helical gear train configurations, to establish minimum lubrication conditions while maintaining ultra-safe operations, will be completed.

Gear-crack propagation analysis tools, as well as specific gear experiments will be used to develop three dimensional (3D) boundary element/fracture mechanics analyses. Full-scale experiments will be used to validate conditions where two dimensional (2D) analyses is accurate and the technology will be transferred to industry via an ultra-safe transmission design-guide. Advanced control laws and modes designed to reduce pilot workload and increase safety in low-visibility conditions was developed using an integrated design tool (CONDUIT) and will be fight tested. The goal will be to achieve Level 1 handling quality ratings from pilots flying civil missions in the RASCAL UH-60. Expanding on the key findings of the accident analyses, new efforts will be initiated with helicopter operators and manufacturers to target near-term opportunities for accident reduction. A companion analysis of helicopter incidents will be completed.

In recognition of the critical role that loss of situation awareness has played in previous fatal accidents, methods of measuring and predicting situation awareness will be demonstrated in part-task simulation and efforts to improve detection and avoidance of obstacles, such as wires and poles, will be initiated. During its fourth year, the NRTC will continue to focus on nearer-term opportunities to reduce and improve performance and increase activities in flight safety and reliability. The NRTC will coordinate projects in conjunction with alliances among the FAA, DOD, NASA and industry to assess near-term national needs with a view to maximize leverage of the NASA investment while minimizing duplication. Completing the flight evaluation of Differential Global Positioning System (DGPS) coupled to heliport precision-instrument approach will enable a quantum improvement in integrating rotorcraft into the evolving transportation infrastructure. Demonstrating the structural characteristics of hybrid titanium/graphite-composite structures will provide for improved safety and affordability in engine compartments and other high temperature areas.

In FY 2000, the Rotorcraft program will conduct wind tunnel in conjunction with advanced active control research to reduce vibration, noise and improve performance. Building on the earlier fatigue life prediction of composite structure work, analytical and experimental techniques for tail rotor flexbeams will be established. Upon completion of evaluations of a number of innovative active and passive noise and vibration reduction concepts, the most promising techniques will be chosen for further research. Investigations to develop a fundamental understanding of gear-noise generation will begin and efforts to model the full flight vehicle for development of noise-abatement procedures will continue.

Accurate, flexible analysis modules suitable for use by industry in their integrated design systems will be completed. Rotorcraft safety will be emphasized through the development and evaluation of health and usage monitoring systems and predictive technologies. Methods of predicting and measuring pilot situation awareness will be developed and tested to allow designers the take this key factor into account when designing new systems. Using the situation awareness prediction model the effectiveness of new displays, and other pilot interface technologies for improving pilot situation awareness, will be demonstrated. Specifications for the hardware and format of a cockpit display designed to improve pilot situation awareness will be completed. The NRTC solutions of industry-wide problems will benefit the performance, utility and public acceptance of both helicopters and tilt-rotor concepts. The developed technologies will improve flight-safety with health-management systems, enhance design/manufacture compatibility, and alleviate both interior and exterior noise. Flight safety will be further enhanced through crashworthy design methodologies that account for landing on water or soft soil as well as on firmer surfaces. Proven application of active vibration alleviation with a horizontal-tail surface will provide reduced structure-borne loads and improved vehicle handling qualities.

BASIS OF FY 2000 FUNDING REQUIREMENT

CONSTRUCTION OF FACILITIES

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Replace Fan Blades, National Full-Scale Aerodynamics Complex		2,000,000	(3,400,000*)
Replace Main Drive for 14x22 Foot Subsonic Tunnel		500,000	(7,300,000*)
Total..		2,500,000	(10,700,000*)

* Funds for FY 2000 are included within other R&T Base elements.

A detailed description of these two program direct projects can be found within the MISSION SUPPORT CONSTRUCTION OF FACILITIES section.

BASIS OF FY 2000 FUNDING REQUIREMENT

AERONAUTICAL FOCUSED PROGRAMS

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
High-Performance Computing and Communications.........	45,700	20,600	24,200
High-Speed Research	245,020	180,708	--
Advanced Subsonic Technology	144,400	89,600	--
Aviation System Capacity	*56,700	*53,900	60,000
Aviation Safety	--	--	60,000
Ultra Efficient Engine Technology	--	--	50,000
Total..	491,820	344,808	194,200

*Previously budgeted within the Advanced Subsonic Technology Program

NASA's Aeronautics focused programs address selected national needs, clearly defined customer requirements and deliverables, critical program decision and completion dates, and a specified class of research with potential application. Each of the focused programs is discussed in detail on the following pages.

BASIS OF FY 2000 FUNDING REQUIREMENT

HIGH PERFORMANCE COMPUTING AND COMMUNICATIONS

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
High-performance computing and communications	45,700	20,600	24,200

PROGRAM GOALS

As a key participant of the Federal HPCC program, the primary purpose of NASA's HPCC program is to extend U. S. technological leadership in high-performance computing and communications by accelerating the development, application, and transfer of high-performance computing and communications technologies to meet the engineering and science needs of the U.S. aeronautics, Earth and space science, spaceborne research, and education communities, and to accelerate the distribution of these technologies to the American Public. As international competition intensifies and as scientists push back the frontiers of knowledge, leading-edge computational science is more important than ever. Studies have shown that high performance computing technologies have a significant positive impact on job creation, economic growth, national security, world leadership in science and engineering, health care, education, and environmental resource management. These technologies also enable the missions of many Federal agencies. The goals of the NASA High Performance Computing and Communications (HPCC) program are to accelerate the development, application and transfer of high performance computing technologies to meet the engineering and science needs of the NASA stakeholders.

STRATEGY FOR ACHIEVING GOALS

The HPCC program goals are supported by these specific objectives:

1) Develop algorithm and architecture testbeds that are able to fully utilize high-performance computing and networking concepts and increase end-to-end performance.
2) Develop high-performance computing architectures scalable to sustained TeraFLOPS performance.
3) Develop high-performance networking architectures scalable to enable Gigabits per second aggregate applications traffic.
4) Demonstrate HPCC technologies on U.S. aeronautics, Earth and space science, and spaceborne community research problems.
5) Develop services, tools, and interfaces essential to the distribution of technologies to the American public.
6) Conduct pilot programs in education and the public use of remote sensing data that demonstrate innovative distribution of technologies to the American public.

The NASA HPCC program is currently structured to contribute to broad federal efforts while addressing agency-specific computational problems called Grand Challenges. Specifically, NASA provides resources to develop tools to solve Grand Challenges in five HPCC project areas: Computational Aerosciences (CAS), managed by the Office of Aero-Space Technology; Earth and Space Sciences (ESS), managed by the Office of Earth Science; Remote Exploration and Experimentation (REE), managed by the Office of Space Science; Learning Technologies (LT), managed by the Office of Human Resources and Education; and the NASA Research and Education Network (NREN), managed by the Office of Aero-Space Technology.

	FY 1998	FY 1999	FY 2000
Aero-Space Technology	45,700	20,600	24,200
Earth Science	18,300	14,500	21,900
Space Science...	5,600	8,400	19,500
Education Programs	4,200	4,000	4,000
Total direct HPCC (NASA-wide).............................	73,800	47,500	69,600

The NASA HPCC program is planned and executed in cooperation with Federal agencies, industry, and academia to exchange information about technical and programmatic needs, issues, and trends. Interagency collaboration is fostered through the National Coordination Office which has a full time staff to support the main HPCC coordinating body--the Computing, Information, and Communication R&D Subcommittee (part of the National Science and Technology Council).

Interagency Cooperative Programs:

NSF/DARPA/NASA Digital Library Joint Research Initiative - The National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), and NASA jointly sponsor the Digital Library Joint Research Initiative in order to demonstrate technologies needed to build digital libraries to electronically access NASA science data. This multi-agency effort was initiated in FY 1994 and concluded in FY 1998. NASA, in conjunction with NSF and DARPA, co-funded six research and development projects.

NSF/NASA Distributed Computing – The National Science Foundation (NSF) and NASA are jointly sponsoring research in software technologies needed to manage and operate geographically distributed computing resources. This multi-agency effort was initiated in FY 1998 and represents a key component of an envisioned capability to utilize the nationwide supercomputing assets.

Next Generation Internet (NGI) - NASA is a participant in the multi-agency NGI effort that also includes the Departments of Defense, Energy, and Commerce, and the National Science Foundation. NGI builds on the base of current NASA Research and Education Network (NREN) R&D activities. NASA-sponsored research will focus on network performance measurement, network interoperability, quality of service and network security. NASA will continue to be an early adopter of emerging networking technologies that chart a course for a robust, scalable, shared infrastructure supporting lead users from NASA, the research community, and other government agencies.

National HPCC Software Exchange (NHSE) - The Federal HPCC agencies working in concert with academia and DoE laboratories developed a National HPCC Software Exchange to provide an infrastructure that encourages software reuse and the sharing of software modules across organizations through an interconnected set of software repositories. This multi-agency effort was initiated in FY 1992 and was concluded in FY 1998.

PetaFLOPS Initiative - The current Federal High Performance Computing and Communications Program is working toward achieving TeraFLOPS (one trillion floating operations per second) computing. However, experts in government, academia and industry have realized that capabilities beyond TeraFLOP-level computing systems will be required in the future. As a result, NASA, NSF, DoE, DARPA, National Security Agency, and the Ballistic Missile Defense Organization are developing technologies to support PetaFLOP (one million-billion floating operations per second) computing systems. The NASA HPCC Program, in coordination with the Information Technology Research and Technology Base Program, is providing “seed” funding in PetaFLOP computing architecture research.

The following discussion describes the projects managed by the Office of Aero-Space Technology.

Computational Aerosciences

The Computational Aerosciences (CAS) project is addressing the high-end computing needs of the aerospace community and has evolved during the course of the Project to support the development of the computing tools that the aerospace industry seeks. The CAS objectives are: to accelerate development and availability of high-performance computing technology of use to the U.S. aerospace community; to facilitate adoption and use of this technology by the U.S. aerospace industry; and to hasten emergence of a viable commercial market for hardware and software vendors to exploit this lead. CAS targets advances in aeroscience algorithms and applications, system software, and computing machinery that will enable more than 1000-fold increases in system performance early in the Twenty-first Century. These computational capabilities will be sufficiently characterized such that they can be rapidly integrated into economical design and development processes for use by U.S. industry. Although CAS does not develop production computing systems, CAS technology and the characterization of existing hardware and software will enable the development of full-scale systems by industry and will make commercial ventures into this area more attractive.

NASA Research and Education Network

The NASA Research and Education Network (NREN) project is extending U.S. technological leadership in computer communications through research and development that advances leading edge networking technology and services. NREN is NASA’s part of the Federal Next Generation Internet (NGI) and serves the NASA community under the NGI umbrella. As part of the Federal Computing, Information, and Communications (CIC) R&D Large Scale Networking (LSN) Program, the main goal of NGI is to assure continuing U.S. technological leadership in communications through research and development that advances the leading edge of internetworking technologies and services. The Next Generation Internet initiative is a multi-agency Federal partnership with industry and academia to develop significantly higher performance networking technologies and systems enabling next-generation distributed applications between scientists, engineers, and computing resources. The NGI initiative connects universities and Federal research institutions with high-speed networks that are 100 to 1,000 times faster than today's Internet, promotes experimentation with the next generation of networking technologies, and demonstrates new applications that meet important national and agency goals.

SCHEDULE AND OUTPUTS

Install 100-250 **GigaFLOPS** sustained TeraFLOPS-scaleable testbed. Plan: June 1998 Actual October 1998	Install testbed and measure scalability and performance against success criteria. Delay due to availability of vendor hardware. A large-scale 256-processor ORIGIN2000 system manufactured by Silicon Graphics Inc. (SGI) has been acquired, installed and brought to operational testbed status. Over 100 GigaFLOPS has been demonstrated on industry-standard benchmark codes. In order to achieve this unique system, specific hardware and software was developed under a Memorandum of Understanding between NASA and SGI to combine two 128-processor machines into a larger single testbed
Demonstrate a portable, scaleable programming and runtime environment for Grand Challenge applications on a TeraFLOPS-scaleable system. Plan: September 1998 Actual September 1998	Demonstrate that applications scale logarithmically with the number of processors and are portable to all current testbeds. A runtime partners. In addition, specific runtime tools for code environment for the Numerical Propulsion Simulation System has been demonstrated and delivered to industry parallelization, debugging, job management, computing system management have been demonstrated on multiple computer testbeds.
Demonstrate 200-fold improvement over FY 92 baseline in time to solution for Grand Challenge application on TeraFLOP testbeds. Plan: June 1999	One application from each project in the selected test cases must scale logarithmically or better and have processor factor speed-up at least 50% of ideal, be portable to all testbeds, and perform at 200 times its current baseline.

Demonstrate 500 times end-to-end performance improvement of Grand Challenge and/or NASA mission applications based on FY 96 performance measurements across NASA NREN testbeds over 622 Mbps wide area network. Plan: September 1999 Revised March 2000	Performed at least three demonstrations at 500 times more end-to-end performance improvement over FY 96 baseline. Additional time is required to address the newly selected NASA applications.
Establish an international Next-Generation Internet eXchange (NGIX) Plan: January 2000	Demonstrate connectivity across an international Next-Generation Internet eXchange.
Demonstrate multicast and quality of service (QoS) technology in a hybrid networking environment Plan: June 2000	Provide at least two demonstrations of multicast and QoS technology in a hybrid (wireless and ground) networking environment.
Demonstrate time-to solution improvements for grand challenge applications on HPCC testbeds Plan: September 2000	Demonstrate at least a 400-fold improvement over 1992 baseline in time-to-solution for one grand challenge application in the area of computational aerosciences.

ACCOMPLISHMENTS AND PLANS

During FY 1998, the NASA HPCC Program's **Computational Aerosciences** (CAS) Project (in coordination with the Information Technology R&T Base Program) installed a computing testbed that will allow evaluation of prototype systems, subsystem interfaces and protocol standards. At the core of this newly installed testbed are two 128-processor and one 64-processor Silicon Graphics Inc. (SGI) ORIGIN 2000 machines installed at NASA Ames Research Center. Working closely with SGI under a Memorandum of Understanding (MOU), specialized hardware and software is being developed to link the two 128-processor machines together into a unique, 256-processor system capable of over 100 GigaFLOPS during benchmark execution. In cooperation with the Consolidated Supercomputing Management Office (CoSMO), an additional two 16-processor SGI ORIGIN 2000 systems were installed at NASA Langley and NASA Glenn Research Center to continue and extend the metacenter research that was started with the original IBM SP2 systems.

To provide an effective testbed system for Grand Challenge researchers, the CAS Project completed the development of key software tools for a portable, scalable programming and runtime environment. This environment was demonstrated with the Numerical Propulsion System Simulation (NPSS) and the National Cycle Program (NCP) efforts, an object-oriented framework for High-Speed Civil Transport (HSCT), work on legacy code migration, and the Parallel Graphics Library for 3-D visualization. Planning was started for development of a computational grid system (called Information Power Grid) -- an omnipresent hardware and software infrastructure that links computational resources in a seamless and reliable way.

The CAS Project also continued to make significant advances towards meeting the goal of 200-fold improvement in time-to-solution for Grand Challenge problems. Large-scale multidisciplinary simulations on representative high-speed civil transport and advanced subsonic aircraft continue to test the limits of modern parallel supercomputers while providing the pacing applications for further system software developments. The coupling of multidisciplinary tools within a collaborative environment is enabling complex propulsion system simulations and is on track towards meeting the goal of 24-hours turn around for full aircraft engine simulations.

Also in FY 1998, the **NASA Research and Education Network** (NREN) Project initiated its support of the federal Next Generation Internet (NGI) initiative. NREN installed high performance interconnections with the research networks of other federal agencies and conducted research into network quality of service issues and multicast scalability. During the year, the NREN Project designed and implemented Next Generation Internet Exchange–West (NGIX-West) and cooperated in establishing the NGIX-Mid America (NGIX-Mid). This activity demonstrated over 100-fold increases in capability to access NASA’s high performance resources by Grand Challenge university researchers.

In FY 1999, the CAS objective is to improve the time-to-solution for Grand Challenge applications using a newly-installed TeraFLOPS testbed. CAS applications will meet the goal of performing at 200 times the established baselines. This will also be supported by NREN/NGI technologies through NREN goals of enabling network-intensive applications. NREN will address specific applications both relevant to NASA missions and providing the pacing requirements for further networking research and implementation.

While continuing to use high-end computing systems, CAS will begin more in-depth efforts to develop computational grids and will increase its work on computational grid concepts through expanded collaborations with academia, NSF, and DARPA. The prototyping of a computational grid will seamlessly link NASA resources—computers, data, instruments, and people—into an interdisciplinary problem-solving and decision-making environment. This effort is driven by: (1) NASA requirements to make more effective and coordinated use of existing and future computational assets, and (2) the need for collaboration among individual groups that are using advances in software technology to develop sophisticated problem solving systems. By recognizing the similarity in the underlying approaches to meeting these needs, an overall system can be developed that provides an improved environment for resource management, while at the same time providing a uniform architecture for software development—from systems software (including security, resource management, etc.) to the domain applications. During FY 1999, the focus of this effort is on demonstrating numerically-intensive applications on a set of distributed computer resources from both NASA and NSF.

In FY 2000, CAS will continue to improve time-to-solution for Grand Challenge applications while implementing initial software to demonstrate a prototype distributed high-performance testbed (computational grid). Along with the installation of HPCC's Earth and Space Science testbed, the CAS computational grid testbed will provide the vital computing resources required to achieve 1,000-fold improvements over established baselines. NREN will demonstrate applications that demand high-performance network capabilities, in some cases focusing its research on the same applications as CAS and ESS. NREN efforts will focus on the development and testing of mechanisms for scheduling guaranteed network quality of service to meet real-time bandwidth, latency and error tolerance requirements. This vital work supporting Next Generation Internet (NGI) will increase the quality, security and certainty of Internet transmissions and on the network capable of 1,000 times the capacity of the baseline.

BASIS OF FY 2000 FUNDING REQUIREMENT

HIGH-SPEED RESEARCH

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
High-speed research	245,020	180,708	--

PROGRAM GOALS

Studies identified a substantial market for a future supersonic airliner — or High-Speed Civil Transport (HSCT) — to meet the rapidly growing demand for long-haul travel, particularly across the Pacific. This market could support 500 to 1,000 HSCT aircraft, creating a multi-billion dollar sales opportunity for its producers. Such an aircraft may be essential for capturing the valuable long-haul Pacific Rim market. Market studies indicate that the successful development of a domestic HSCT results in $200 billion in sales and 140,000 jobs for U. S. industry. As currently envisioned, an HSCT aircraft would carry 300 passengers at Mach 2.4 on transoceanic routes over distances up to 6,000 nautical miles at fares comparable to subsonic transports.

NASA has been developing the technologies that industry needs to design and build an environmentally compatible and economically competitive HSCT for the 21st century. The High-Speed Research (HSR) program goal was to have the technology available to enable an industry decision on aircraft production.

STRATEGY FOR ACHIEVING GOALS

In the early 1990's, studies indicated that an environmentally compatible and economically competitive HSCT could be possible through aggressive technology development. Since then, NASA concentrated its investments in the pre-competitive, high-risk technologies. While NASA has continued to be successful and is on track to meet the original program goals, recent market analyses and estimated industry development costs of $15 to $18 billion have made the HSCT considerably less attractive to NASA's industry partners. Cost of development in this amount puts the aircraft industry at significant financial risk. Current analyses indicate that further significant investments in technology development are required to ensure an economically viable HSCT. Consequently, the cost of development has led the major aircraft manufacturer to the conclusion that the introduction of an HSCT cannot reasonably occur prior to the year 2020. For these reasons, industry has reduced their commitment to this area and has scaled back their investments. Given other pressing needs in the Agency in general, and aeronautics in particular, the HSR program will be concluded by the end of FY 1999.

Since its inception, NASA's HSR program has made significant contributions to aeronautics state of the art. It has provided a public-sector catalyst in addressing this important opportunity with U. S. industry through a two-phase approach. The first phase, successfully completed in 1994, defined HSCT environmental compatibility requirements in the critical areas of atmospheric effects, community noise and sonic boom and several milestones—including completion of a preliminary noise assessment; selection of engine cycle, inlet, and nozzle concept; selection of candidate flight deck concepts; identification of preliminary wing and fuselage structural concepts; and, ultimately, definition of a technology concept—contributed to a technology foundation that provided confidence that the necessary technology could be developed. The second phase was a cooperative program with U. S. industry, directed at developing and validating designs, design methodologies and manufacturing process technology for subsequent application by industry in future HSCT aircraft programs to ensure environmental compatibility and economic viability. As HSR Phase II is concluded it will have exceeded the original HSR Phase II program goals planned through FY 1999 for environmental compatibility and economic viability. As an example of the highly successful nature of this program, the technology concept airplane (TCA) baseline defined in December 1998 is several decibels quieter than the original HSR noise goals. Accomplishments contributing to TCA definition include successful completion of subscale combustor tests and large-scale nozzle tests; selection of turbine airfoil alloy and turbomachinery disk material; selection of a combustor configuration; completion of wing and fuselage subcomponent tests; and completion and evaluation of supersonic laminar flow control tests.

Langley Research Center (LaRC), the lead center, was responsible for policy and program implementation, project planning and funding allocation, vehicle systems engineering and integration, and direct airframe contractor interface and management. At the NASA Aeronautics Centers (Ames Research Center (ARC), Dryden Flight Research Center (DFRC), LaRC and Glenn Research Center (GRC)), the Center Directors provide personnel and facilities to conduct research, analysis and program management in support of the program. GRC was also responsible for the propulsion contractor interface and management.

The team of primary HSR contractors consisted of airframe, propulsion system and advanced flight deck companies. These contractors were responsible for: the research, development and validation of specific technologies; the development and assessment of a next-generation High-Speed Civil Transport (HSCT) concept and configuration; the system-level integration of the advanced technologies being developed; and the conduct of associated tasks, such as mission analysis and database development. The primary propulsion contractors were the team of Pratt & Whitney and General Electric Aircraft Engines. The primary airframe contractor was Boeing. The advanced flight deck contractor was Honeywell International. ARC provided significant support directly to LaRC in advanced flight deck development, in computer modeling and simulation, and in economic analysis. DFRC provided support for flight-related activities. LaRC was responsible for integration of all elements of the program and GRC is responsible for propulsion systems technology integration.

The HSR program was enhanced by participation, in coordination and cooperative efforts to exchange information and data, with other NASA organizations and federal agencies that include:

- The Atmospheric Effects of Stratospheric Aircraft Panel, that includes participation by NASA's Office of Mission to Planet Earth, Environmental Protection Agency, Federal Aviation Administration, National Oceanic and Atmospheric Administration, National Science Foundation and Department of Defense. The panel provides guidance and evaluation of research related to the effects of high-speed civil transports on the upper atmosphere;

- The FAA/NASA Coordinating Committee provided the framework for developing and defining HSCT certification requirements; and

- The Department of Defense provided a cooperative forum for advanced engine technology development via its Integrated High Performance Turbine Engine Technology (IHPTET) initiative.

SCHEDULE AND OUTPUTS

Engine Static Test (Large Scale Model Build 1) Complete. Plan: March 1998 Actual: February 1998	Design, fabricate and test a 60 percent-scale nozzle model. Static performance and acoustic data will be collected. Enabling Propulsion Materials project will provide carbon matrix composites (CMC) liner panels and thermal protection system to be tested. The propulsion elements of the program were re-planned to provide better connectivity between materials and components and to improve the test plan to ensure that testing occurs at appropriate scales. Completed test and analysis of data gathered from 60 percent-scale model nozzle test. Aero-acoustic data calibrated prediction tools utilized for predicting large scale nozzle performance using small-scale nozzle data.
Combustor Configuration Selected. Plan: May 1998 Actual: May 1998	Combustor selection will be based on results of sector testing with advanced metallic and ceramic matrix composite liners, annular rig testing, manufacturing infrastructure assessment, analyses, and preliminary designs of the two most promising combustors. The subscale combustor annular rig tests will not be performed for the rich burn/quick quench/lean burn configuration prior to down- select. This was a result of a management assessment, which indicated that the data to be acquired would not impact the down-select. The Lean Premixed Prevaporized (LPP) concept was chosen based primarily upon ultra low levels of NOx achieved in subscale sector tests and no identified showstoppers from a potential product development path.
Preliminary Flight Deck Configuration Selected. Plan: July 1998 Actual: July 1998	Down-selection of preliminary flight deck configuration including: choice of control inceptor; selection of basic External Visibility System concept; evaluation of terminal area guidance and control concepts; development of decision-aiding concepts; confirmation of flight deck design and automation philosophy; and provision of both electronic and physical cockpit mock-ups.

Subcomponent Test Articles. Plan: September 1998 Actual: October 1998	Delivery and preparation of several wing and fuselage subcomponent articles for structural testing. All wing and fuselage subcomponents have been designed, fabricated and prepared for structural testing.
Subcomponent Test Data (Materials and Structures). Plan: September 1998 Revised: March 1999	Release of data acquired during static and damage-tolerant testing of wing and fuselage sub-component articles. All data acquired during wing subcomponent testing and during five of seven fuselage subcomponent tests compiled and released. Remaining two fuselage subcomponents will be tested and data released by end of March 1999.
Component Materials Selection. Plan: September 1998 Revised: March 1999	Materials and structural (M&S) concepts will be selected for wing and fuselage component test articles. Selections will be based on material performance, structural efficiency, and production costs as determined by testing and analytical studies. M&S concepts have been selected for wing component test article; M&S concepts for fuselage component test articles will be selected in March 1999. Selections are based on material performance and structural efficiency and uses analyses and test data.
Phase II Assessment of Atmospheric Impact. Plan: September 1998 Revised: February 1999	Complete the assessment of environmental compatibility of HSCT incorporating HSR emissions reduction technology. Draft report complete; late breaking data from field observations and model findings are being incorporated prior to publication of the report.
Technology Configuration Defined. Plan: December 1998 Actual: December 1998	Define an optimized NASA/Industry technology baseline airplane configuration resulting from HSR technology validation development and down-selection processes. Make final selection of technology elements for the airplane and embody these features in the baseline airplane. An HSR Technology Configuration baseline airplane was defined that met or exceeded all exit criteria using HSR technology expected from Phase II.
Full Scale Design Build 1 Designed; Configuration/Materials (Decision). Plan: June 1999 Revised: March 1999	Complete preliminary and detailed design of a full-scale actuated nozzle. Configuration and component material selections determined. Due to program termination, the nozzle design effect will be terminated after the Conceptual Design Review (CDR) scheduled for March 1999. The preliminary and detailed design efforts will not be initiated nor completed.

1-Lifetime Accelerated Test Data. Plan: June 1999	Initial release of 1-lifetime of data acquired during accelerated thermal-mechanical-fatigue testing of materials; for use in validating analytical methods for predicting material degradation.
Full Scale Annular Combustor, Rig, and Liner Design - Configuration/Materials Plan: September 1999 Actual: February 1999	Complete detailed design of the selected HSCT scale combustor and life prediction analysis for the liner. Design temperatures and stresses in the liner are within the capabilities of the EPM developed material. Drawings are released for fabrication. Due to re-planning for termination of this program, the work toward this milestone will cease and no detailed design effort (or associated efforts such as life prediction) will be completed and no interim products will be available.
Program Technologies Documented Plan: September 1999	In-depth documentation of HSR Phase II technologies incorporated in the HSR Technology Concept Level 1 milestone of December 1998 will be completed along with a concise summary of lessons learned in HSR work. Technology advances achieved in the HSR program will be appropriately integrated into ongoing and planned NASA programs where data restrictions allow.

ACCOMPLISHMENTS AND PLANS

During FY 1998, the HSR program continued developing the technology database to raise the Technology Readiness Levels from 2-3 (technology concept formulated/proof of concept) to 3-4 (proof of concept/component test in laboratory environment). The Tu-144 flight testing was completed, and experimental data reduced, analyzed and compared with HSCT design tools. Analytical methods for accelerating the combined thermal-mechanical-fatigue testing to match real-time degradation parameters for composite and metallic materials were released. The HSR simulator cab was integrated on the Langley Research Center Cockpit Motion Facility. Potential flight deck concepts were installed, including strategic and tactical flight path management, external visibility system display design, and center stick control inceptor, and initial evaluations conducted. These data are being utilized to update the flight deck technology configuration benchmark report and 3D electronic benchmark configuration model. Benchmark concepts include those for a functionally integrated flight deck configuration, an external vision system, control laws and flight controller, flight path management (strategic and tactical), crew interaction with automation, crew autoflight integration, multi-function displays/controls, and management of non-normal situations. Design, fabrication and testing of a 60 percent-scale nozzle model was performed to obtain static performance and acoustic data. Ceramic matrix composite liner panels and thermal protection system were also tested. Emissions, performance, material durability and operability testing of subscale lean and rich combustor sector at simulated cruise and landing and take-off conditions were completed on subscale test rigs. A combustor design was selected based on results of sector testing with advanced metallic and ceramic matrix composite liners, manufacturing infrastructure assessment, analyses, and preliminary designs of the two most promising combustors. The aeroelastic characteristics of the technology concept airplane design were optimized using multidisciplinary optimization for structures, aerodynamics, propulsion, and controls employing detailed finite element and computational fluid dynamic tools. Several wing and fuselage subcomponent articles were tested and correlated to analysis predictions. The engine concept technical readiness was reassessed using systems analyses that capture small-scale test results and analysis, material feasibility and manufacturing infrastructure.

As part of a planned orderly closeout at the end of FY 1999, the following activities will be concluded: Complete TIFS flight tests for external vision validation and validate a display, guidance, and control system. Complete airframe materials durability composite database under isothermal without load, complete all subcomponent testing and analysis and thermomechanical fatigue tests of thick laminate joints. Complete interim fabrication database of PETI-5. Complete half-span aeroelastic test in LaRC Transonic Dynamics Tunnel. Complete high-lift configuration evaluation. Complete high-speed performance validation. Complete an assessment of the environmental compatibility of the HSCT incorporating new emissions reduction technology. Complete design and fabrication of full-scale combustor sector rig. Complete combustion environment testing of Ceramic Matrix Composite (CMC) liner parts for ultra low emissions combustor. Compete conceptual design of full scale technology demonstrator nozzle. Complete initial assessments of innovative ultra low noise nozzle concept. Provide improved aeroacoustic scaling methodologies. Complete initial assessment of "waverider " inlet concept. Complete fabrication of subscale fan-inlet acoustics test rig. Complete scale-up feasibility effects of nozzle advanced materials (superalloy). Complete nozzle materials characterization studies. Complete down-selection process for turbomachinery disk and turbine alloy materials. Complete a technology identification study to meet new requirements for “Lessons Learned” documentation. Complete summary and lessons learned documentation for all technology areas for transfer, as appropriate, to other focused programs and base activities.

BASIS OF FY 2000 FUNDING REQUIREMENT

ADVANCED SUBSONIC TECHNOLOGY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Advanced subsonic technology	*144,400	*89,600	--

*Capacity had previously been included within the Advanced Subsonic Technology Program and is now identified as a separate focused program.

PROGRAM GOALS

With competition from foreign competitors greatly increasing, affordable, innovative technology is critically needed to help preserve the U.S. aeronautics industry market share, jobs, and balance of trade. Exports in large commercial transports make a significant contribution to the U.S. balance of trade. However, according to industry estimates, the U.S. worldwide market share has slipped from a high of 91 percent during the 1960's to less than 67 percent today. Increasing congestion in the aviation system and growing concerns about the environmental compatibility of aircraft may limit the projected growth and more stringent noise-based restrictions and engine emissions standards are expected in the near future.

In addition, state government and corporate leaders recognize the vital importance of the infrastructure of small airports across the Nation that provides access for suburban, rural and remote communities to the national air transportation system. Accordingly, planning has been initiated, with the FAA, for a Small Aircraft Transportation System (SATS) technology development and deployment effort. The results of the current NASA general aviation investments create the basis for revolutionary new small aircraft and pilot training capabilities for business and personal transportation. This new generation of aircraft (as well as retrofit of the new technologies to the current fleet) sets the stage for national strategies and investments in “smart” operational capabilities and airports for the SATS.

The goal of NASA's Advanced Subsonic Technology (AST) program was to develop high-payoff technologies, in cooperation with the Federal Aviation Administration (FAA), the U.S. aeronautics industry and academia, to benefit the civil aviation industry's international competitiveness and the public. These technologies were aimed at reducing travel costs while increasing safety, reducing civil aircraft impact on the environment, and increasing doorstep-to-destination travel speeds. The success of the AST program has resulted in significant contributions to technology readiness that will preserve our Nation's economic health and the welfare of the traveling public, and mobility and accessibility to more destinations in the national air transportation system.

STRATEGY FOR ACHIEVING GOALS

The AST program was planned and designed to develop, in partnership with the FAA, the U.S. aeronautics industry and universities, high-payoff, high-risk technologies to enable a safe, highly productive global air transportation system that includes a new generation of environmentally compatible, operationally efficient U.S. subsonic aircraft. The critical needs were selected on the basis of industry/FAA technology requirements to provide a focused and balanced foundation for U.S. leadership in aircraft manufacturing, aviation system safety, and protection of the environment.

The development of these technologies has been an important step in accomplishing the enabling technology goals of the Enterprise's ***Global Civil Aviation*** and ***Revolutionary Technology Leaps*** Pillars. The projects of the AST program are aligned within the following four major thrusts that are consistent with the Enterprise goals defined under the two pillars: Safety, the Aging Aircraft project; **Environment**, including the Noise Reduction, Environmental Assessment and Emissions Reduction projects; **Reduced Seat Cost**, including the Airframe Methods and Design Environment Integration, Systems Evaluation, Airframe Materials and Structures and Engine Systems projects; and **General Aviation**.

Due to other pressing Agency needs in general and aeronautics needs in particular, the AST program will be concluded in FY 1999. Aggressive technology transition plans were pursued in order to mitigate the significant risk to successful technology transfer to industry as a result of early termination. Budgetary constraints notwithstanding, the AST program has been successful and progress was made toward meeting the current program goals.

Safety

With pressures on the bottom line, airlines are continuing to fly their aircraft beyond the typical design life of 20 years, or approximately 60,000 flight hours. Today, the average age of the world's operating fleet is over 12 years old, and approximately 1000 airplanes, or one-fourth of the operating fleet, is more than 20 years old. More than 500 of those airplanes are 25 years or older, and some airlines are planning to keep their airplanes flying past 30 years. This trend, simply based on the lower cost of inspection and maintenance versus the cost of acquiring new airplanes, will continue in the future as airlines attempt to attain positive balance sheets. However, the current inspection techniques are based largely on visual methods supported by single point measurements. Due to the reliance on human inspection, the results are subjective and as the airplanes age, inspection becomes more time consuming and costly. Methods for predicting the residual strength remaining in aging aircraft and cost-effective, broad-area nondestructive evaluation methods have been developed to reduce cost and time and eliminate error.

Environment

Aircraft noise is an issue, both nationally and internationally, prompting airports to operate with strict noise budgets and curfews that restrict airline operations. International treaty organizations are actively considering more stringent noise standards that will impact the growth of the aerospace industry. Noise curfews and inefficient noise abatement terminal area procedures exacerbate congestion. In 1969, the FAA issued Federal Aviation Regulation, Part 36 (FAR 36) to prevent the increase in noise produced by transport aircraft. In addition, concern for local noise impact issues often delays, and is sometimes the reason for not pursuing needed airport capacity improvements. In 1991, the FAA took an additional step by requiring that all Stage 2 aircraft be phased out by the year 2000. It is unlikely that the environmental community will tolerate increased overall noise levels due to growth in the number and size of new aircraft after the year 2000. The Noise Reduction project, in cooperation with U.S. industry and the

FAA, targeted technologies to reduce, by the year 2000, the community noise impact for future subsonic transports by ten decibels (dB) relative to the 1992 state-of-the-art. The approach was designed to develop noise reduction technology for engine source noise, nacelle aeroacoustics, engine/airframe integration, interior noise, and flight procedures to reduce airport community noise impact, while maintaining high efficiency, with objectives achieved via systematic development and validation of noise reduction technology. The timing of the technology development was consistent with the anticipated timing of recommendations for increased stringency. Fundamental work in this area will transfer to the Airframe Systems program to reach the ten decibel goal planned for the AST program.

Propulsion emissions has gained significant visibility in international organizations, such as the International Civil Aviation Organization (ICAO), Committee on Aviation Environmental Protection (CAEP). These organizations are considering more stringent standards for engine emissions during landing and takeoff operations—i.e., below 900 meters altitude—as well as new standards for cruise operations. In the past, new combustor concepts and technologies have produced cleaner burning engines to offset the negative trends of more fuel efficient, higher pressure ratio engines. Additional new combustion concepts and technologies, including new improved fuel injectors and higher temperature liner materials, will be required to meet more stringent standards. In cooperation with the U.S. industry, NASA developed low emission combustor technology with the objective of reducing the environmental impact of future engines through reduced engine emissions. The goals of the Emissions Reduction project were to reduce nitrogen oxide emissions, by at least a factor of two or 50 percent within seven years, and a factor of three or 70 percent within ten years for both large engines and regional engines relative to the 1996 ICAO Standards. Research and development focussed on low emission combustors to be incorporated into the next generation of very-high-bypass ratio engines and derivatives, or enhancements of engines currently in service. Key technology development required for an ultra-efficient engine in the areas of propulsion emissions and environmental assessment will be transferred to the Ultra-Efficient Engine Technology program.

Environmental Assessment develops a scientific basis for assessing the atmospheric impact of subsonic commercial aircraft. The goals were to determine the current and future impact of aviation on the atmosphere and to provide scientific assessments of global ozone perturbations and climate change. Overall program direction and selection of investigators was guided by an advisory panel comprised of respected members of the scientific and aviation communities. Elements of atmospheric research (e.g., modeling, laboratory studies, and atmospheric observations) were complemented by studies unique to the aviation problem (engine exhaust characterization, near-field interactions, and operational scenarios). Current scientific understanding of aircraft effects was published in the IPCC Special Report: Aviation and the Global Atmosphere, and AST-sponsored research scientists made a substantial contribution to this report which focuses on subsonic aviation.

Reduced Seat Cost

To insure that the increased air travel requirements predicted for the 21st Century can be adequately satisfied by the U.S.-built aircraft, the focus of the Reduced Seat Cost thrust was to develop and validate aggressive technologies that significantly advance the state of the art in transport aircraft design and production. In order to realize this potential, the goal for the Airframe Methods and Design Environment Integration project was to enhance delivery of integrated design methodologies, new aerodynamic concepts, and faster design cycles. These concepts and tools provide superior aircraft and improved market responsiveness while reducing operating and ownership costs, environmental impacts, and aircraft development risks. As a result of early termination and final year budget reductions, the resultant technical objective is a demonstration by the U.S. transport aircraft industry that deliverables will provide a one- to two-percent reduction in aircraft direct operating costs (DOC) compared to 1995 baseline technology levels, and a 15- to 25-percent reduction in aerodynamic design cycle time over 1995 practices.

Another vital project, Airframe Materials and Structures, was aimed at gaining significant improvements in efficiency of transport aircraft while reducing costs. The goal of this project was to develop and validate innovative fabrication methods and models that offer a paradigm shift in robust, lightweight composite airframes. The primary technical objectives were verification of a composite structure wing design that costs 10 to 20 percent less to acquire and weighs 10 to 30 percent less than an aluminum aircraft sized for the same payload and mission. Significant cost savings are attributed to reducing part count with composite structural concepts and using revolutionary automated fabrication methods. This equates to potential savings in aircraft DOC of five percent. As a result of early termination and budget reductions in FY 1999, methods were validated and verified using one large-scale semispan wing test article.

In order to realize the full potential for propulsion capabilities, the goal of the Engine Systems project was to develop highly fuel efficient, maintainable, reliable and fault tolerant technologies and design methodology which meets the performance, emissions (including carbon dioxide) and safety requirements for the next generation of air transport systems. The goal of the project was to reduce the engine design and development cycle time. Aerodynamic, aeroelastic, and cooling (heat transfer) analytical models and computational tools were developed and validated using affordable advanced turbomachinery components (which are expected to result in a 30-percent reduction in design and development cycle time and engine testing). Research and development focussed on affordable advanced turbomachinery; high-temperature disk and blade materials; improved controls and accessories; advanced propulsion mechanical components; and lightweight, affordable engine static structures. The products of this project will be incorporated into the next generation of very-high-bypass ratio commercial engines and derivatives, or enhancements of engines currently in service, and technology development will transition to the new Ultra-Efficient Engine Technology program.

Finally, the Systems Evaluation project allowed for a full understanding of the relative payoff of emerging technologies. This project provided a systems analysis capability that is essential in the development of a credible assessment of the impact of NASA aeronautics technologies on the U.S. industry. The goal of this project was to provide credible assessments of the impact of alternative emerging civil aeronautics technologies on the integrated aviation system. Such assessments assist in planning new initiatives, as well as assist customers of AST technologies in understanding the impact and potential on an integrated aircraft and system. To better assess aeronautics technologies, an aviation system assessment capability (ASAC) linking the multidisciplinary and multifaceted aspects of the global aviation system was developed. This is significantly beyond the capabilities of any single analytical tool available today, though many of its constituent components exist in specialized areas, such as air traffic management.

General Aviation

General aviation in the U.S. represents approximately one-third of the nine and one half billion air miles flown by all civil aviation annually; about two-thirds of these hours are “commercial” or revenue-generating operations. In addition, roughly 90 percent of all airports in the U.S. are available exclusively for general aviation, and it accounts for about 40 percent of all instrument operations at towered airports. However, during the 1980’s and early 90’s, annual U.S. production of general aviation aircraft fell to less than five percent of the 1978 level and the infrastructure of small airports began to deteriorate. In partnership with U.S. industry, the FAA and universities, through a 50/50 cost-share joint venture, NASA established the Advanced General Aviation

Transport Experiments (AGATE) Alliance. The goal of the Alliance is to support revitalization of U.S. general aviation through development and deployment of advanced avionics, airframe, pilot training, and engine-related technologies, creating the basis for a SATS. Improvements in safety, affordability, utility, ease-of-use, and reliability of the next generation of general aviation aircraft for business and personal transportation result from the application of these technologies. In the process, small aircraft transportation expands the mobility and accessibility of the Nation's smaller communities within the national air transportation system. Achieving the goal supports the expansion of the Nation's economy by better serving the vast infrastructure of over 18,000 general aviation landing facilities, which includes 5,400 public-use facilities. This expanded use of general aviation is expected to fuel expansion of the national economy by bringing the "off-airways" communities into the mainstream of U.S. commerce. In addition, SATS can help mitigate the pressure on capacity for the hub-spoke airport system as well as on demand for additional lane-miles of highway infrastructure.

SCHEDULE AND OUTPUTS

Safety

Complete field demos for tech transfer to industry

Plan: September 1998
Actual: September 1998

Complete field demonstrations to illustrate technology utilization and conduct focused workshops to transfer all technology to the instrument manufacturing industrial community.

Final milestone for this project. New analysis methodologies, in the form of structural integrity analysis computer codes, have been developed, experimentally verified, and are now in use by all U.S. airframe manufacturers. An Engineering Handbook describing the methodology, and including the computer codes and experimental data, is available on the web at http://irwin.larc.nasa.gov/handbook/index.html. Nondestructive inspection devices have been developed for disbond, corrosion, and crack detection that have resulted in commercial product licensing agreements.

Environment

Emissions Reduction: Evaluate flametube combustor concepts

Plan: March 1998
Actual: December 1997

Advanced flametube combustor concepts will be evaluated for their potential to reduce NOx by conducting flametube experimental tests at 50 atmospheres to simulate engine combustor operating conditions.

Advanced low NOx combustor concepts demonstrated 50-percent reduction in flametube tests and showed promise for achieving the 70-percent NOx reduction goal. As a result of refocusing, low emission combustor development transitioned from fundamental flametube testing to sector combustor testing 50-percent reduction fuel injectors (a more relevant environment) and allowed early completion of this work.

Noise Reduction: Demonstrate flight-applicable active noise control on large engine. Plan: December 1998 Deleted	Demonstrate that active noise reduction technology is sufficiently mature for flight application on a large engine. In response to industry input, the active noise control work was re-planned and, as a result, the decision was made to concentrate future active noise control work on the fan blade passage frequency tone.
Emissions Reduction: Demonstrate reduction of future large engine emissions of NOx by 50 percent. Plan: September 1999	Demonstrate in a full annular combustor rig a low emission combustor that meets the 50 percent NOx goal for large engines.
Environmental Assessment: UNEP/WMO Ozone/IPCC climate reports input. Plan: September 1999	Provide input for preparation of United National Environmental Panel (UNEP)/World Meteorological Organization (WMO) ozone and Intergovernmental Panel on Climate Change (IPCC) climate assessment reports.
Reduced Seat Cost	
Systems Evaluation: Release second generation ASAC. Plan: March 1998 Actual: March 1998	An enhanced Web-based aviation analysis system with integrated model architecture and advanced system models and databases was delivered which provides the assessment of potential technology benefits.
Airframe Materials and Structures: Conduct semispan wing test. Plan: September 1998 Correction:September 1999	In-house semispan wing test conducted to provide critical assessment of revolutionary fabrication methodology and verification of analytical models to provide verification of analysis methodology, and cost and weight reduction data. (Milestone date was incorrectly reported in FY 1999 narrative.) Final milestone for this project.
Engine Systems: Demonstrate improved turbomachinery design. Plan: September 1999	Initial turbomachinery design tools and methods available for validation and application to next generation of highly fuel efficient, environmentally compatible, maintainable and reliable engine systems. Final milestone for this project.

Systems Evaluation: Release final ASAC. Plan: September 1999	Deliver the final functionally validated Web-based aviation analysis system with integrated model architecture and advanced system models and databases will be delivered which will provide the assessment of potential technology benefits. Final milestone for this project.
Airframe Methods: Three-dimensional high-lift analysis methods validated. Plan: September 1999	Calibrated three-dimensional Navier-Stokes methodology that allows for the analysis of subsonic transport configurations including simulation of the propulsion system power effects. Final milestone for this project.
General Aviation	
Complete market assessments. Plan: March 1999	Complete market assessments of current and latent market and assess domestic and international benefits.

ACCOMPLISHMENTS AND PLANS

FY 1998: $144.4 million

In **Safety**, the Aging Aircraft project was successfully completed with the development and commercialization of nondestructive prototype systems for disbond, corrosion and crack detection, and the transfer to the FAA, DOD and industry of verified structural integrity analysis methodology for predicting the onset of widespread fatigue damage, fatigue crack growth, and residual strength of fuselage structure.

In **Environment**, active control technology was validated to reduce engine fan tones in two laboratory, high-fidelity engine simulator tests. Concepts were discovered, optimized and validated at model scale to reduce flap and slat airframe noise sources. A flight test on a twin engine turboprop commuter airplane verified an active structural interior noise reduction concept to control interior propeller tone noise levels. Sector rig tests with advanced low NOx combustor concepts were conducted which demonstrated 50 percent NOx reduction levels. Subsonic Assessment (SASS) completed the second field campaign with the NASA DC-8 flying laboratory. The Subsonic Assessment Ozone and Nitrogen Experiment (SONEX) field campaign was the first attempt to measure subsonic aircraft emission signatures in the North Atlantic flight corridor. SONEX successfully measured a significant NOx and particulate aircraft fingerprint within these flight corridors. The environmental impacts of the current and future subsonic fleet are potentially significant. Current scientific understanding of critical atmospheric processes and the capability of predictive models are adequate only for qualitative assessment of aircraft effects in most areas. Substantial improvements are required in scientific understanding and atmospheric process models to provide quantitative impacts of aviation on the atmosphere. SASS-sponsored research scientists made a substantial contribution to the Intergovernmental Panel on Climate Change (IPCC) Special Report: Aviation and the Global Atmosphere planned for publication in 1999.

In **Reduced Seat Cost**, extended-use disk manufacturing concept was demonstrated to reduce cost by extending engine disk life and maintenance intervals. The final design for the composite semispan wing was updated based upon completion of the subcomponent testing, and the first-ever full-size cover panels utilizing revolutionary stitched composite technology were successfully fabricated for the semispan test article. The technology showed significant cost and time reductions were feasible with the innovative techniques. New, novel computational methods demonstrated a six-fold reduction in design cycle time through automation of high-lift design and analytical methods. An enhanced second generation ASAC was released and utilized by NASA and industry to assess advanced technology impact in the areas of safety, air carrier operations, noise and National Airspace System.

In **General Aviation**, with the definition of system requirements in place, development continued in the technology areas of ice protection, propulsion sensors and controls, human factors for flat-panel displays, COTS-based avionics computer hardware and software, composite materials manufacturing processes, crashworthiness, and digital data link communications systems standards. Additionally, assessments of U.S. and international general aviation markets began to evaluate the potential levels of growth in general aviation. The first students graduated from the AGATE unified instrument-private pilot curriculum with significant savings in cost and time to receive an Instrument Flight Rules pilot certificate. Two new airframe manufacturing partners in AGATE successfully certified the first new general aviation single-engine aircraft in over 16 years, incorporating several NASA and AGATE-derived technologies.

FY 1999: $89.6 million

In **Environment**, an improved and updated community noise impact model to include noise impact minimized flight tracks will be completed and released. Full-scale, static engine demonstrations of advanced engine and nacelle noise reduction concepts will be conducted. Broadband engine fan noise will be investigated in a model-scale, wind tunnel experiment. Sector and full annular testing of low emission combustor concepts will be conducted which will meet the 50-percent NOx reduction goal for large engines. SASS will conduct the Atmospheric Chemistry of Combustion Emissions Near the Tropopause (ACCENT) field mission to further characterize aircraft particle contributions at the regional scale, particularly as they affect cloud nucleating properties of the atmospheric aerosols. Current scientific understanding of aircraft effects will be published in the IPCC Special Report: Aviation and the Global Atmosphere. SASS-sponsored research scientists made a substantial contribution to this report which focuses on subsonic aviation.

In FY 1999, efforts supporting **Reduced Seat Cost** will be completed. Improved turbomachinery design codes will be applied and validated to demonstrate increased capability (highly efficient, environmentally compatible and reliable) engine systems. Testing of the semispan advanced composite wing will be conducted to verify weight (25 percent reduction) and structural performance goals, and wing cover panels will be fabricated to verify the cost reduction goal (20 percent reduction). An analysis method for an integrated aerodynamic design of the wing with the propulsion system will be validated and provided to industry to contribute to a reduced design cycle time. Following completion of evaluations of the earlier release, the operational version of the ASAC computer code, including aviation databases and economic and aviation system analysis models, will be released to complete the Systems Evaluation project.

In **General Aviation**, work will be completed in ice protection and propulsion sensors and controls. The assessments of current and latent general aviation markets will be conducted. The AGATE “highway-in-the-sky” operating capability will begin final development, with the planned certification issues resolution for COTS-based avionics and display hardware and software architecture for the cockpit. Flight training learning modules will be developed for next generation AGATE cockpit systems. Design and manufacturing technology development will continue toward crashworthy composite airframes, including airbags.

BASIS OF FY 2000 FUNDING REQUIREMENT

AVIATION SYSTEMS CAPACITY

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Aviation Systems Capacity	*56,700	*53,900	60,000

*Previously included as a project within the Advanced Subsonic Technology Program

PROGRAM GOALS

In FY 2000, the Capacity project of the Advanced Subsonic Transportation (AST) program will be separated from the AST program and designated a separate program called Aviation Systems Capacity (ASC).

According to airline representatives, delays in the Air Traffic Control System cost U. S. operators approximately $3.5 billion per year in excess fuel burned and additional operational costs. The number of airports experiencing 20,000 hours of delay each year is projected to increase by 50 percent by 2003. Due to environmental issues and cost, only one major new U. S. airport—in Denver—will be opened this decade. With little ability to build new or expand current airports in the populated areas where they are needed, airport delays will continue to grow. More efficient and flexible routing, scheduling, and sequencing of aircraft in all weather conditions is critical to meeting capacity demands. The U. S. aviation industry is investing $6 billion over 20 years to increase airport capacity. However, a gap still exists between the industry's desired capacity and the ability of the National Airspace System to handle the increased air traffic. Another part of the solution to capacity demands is to off-load the major airports by developing short-haul routes among the 5200 public-use airports available throughout the country. Studies conducted by Boeing Commercial Aircraft for NASA and the FAA and by various state and local transportation authorities (e.g., Port of New York and New Jersey Authority) have shown the civil tiltrotor to be a viable candidate for relief of air traffic congestion.

The ASC program supports on the Enterprise's Global Civil Aviation goal of "tripling the aviation system throughput in all weather conditions, within 10 years, while maintaining safety". The goal of the Aviation System Capacity (ASC) program is to enable safe increases in the capacity of major US and International Airports through both modernization and improvements in the Air Traffic Management System and the introduction of new vehicle classes which can potentially reduce congestion, specifically: to increase National Airspace System (NAS) throughput while assuring no degradation to safety or the environment; to increase the flexibility and efficiency of operations within the NAS for all users of aircraft, airports and airspace; and to reduce system inefficiencies.

STRATEGY FOR ACHIEVING GOALS The ASC program is composed of the Terminal Area Productivity (TAP), Advanced Air Transportation Technology (AATT), and the Civil Tiltrotor (CTR) projects. The TAP project develops technology and procedures to support the aviation systems infrastructure by reducing system delays and enabling new modes of airport operation to support

“Free Flight”. The AATT project develops decision making technologies and procedures to provide all airspace users with more flexibility and efficiency, as well as enable new modes of operation that support the FAA commitment to “Free Flight”. The CTR project develops technologies and procedures to overcome inhibitors to a civil tiltrotor operating within an improving and modernized air traffic system. The ASC program works closely with manufacturers, the airlines and the FAA, the technology customers, who are responsible for applying the candidate technologies as operational systems.

In the area of Air Traffic Management R&D, NASA and the FAA have an integrated research and technology development plan, approved by both the NASA Associate Administrator for Aero-Space Technology and the FAA Associate Administrator for Research and Acquisition. An Inter-Agency Integrated Product Team (IAIPT) is responsible for the strategic management of this area of research by the FAA and NASA, assuring that the efforts of both agencies are conducted to maximize the benefits of the research. The IAIPT reports to a NASA/FAA Executive Council, comprised of the appropriate Associate Administrators from both Agencies. Each agency is responsible for the conduct of its Programs. Oversight of the NASA Programs is provided through the NASA Advisory Council. The Ames Research Center is the lead center for the program and each of the three current projects, with the Langley and Glenn Research Centers providing supporting research.

The **Terminal Area Productivity** (TAP) project is focused on increasing capacity at airports. The objective is to provide technologies and operating procedures enabling productivity of the airport terminal area in instrument-weather conditions to safely match that in clear-weather or visual conditions. In cooperation with the FAA, NASA’s approach in TAP is to develop and demonstrate airborne and ground technology and procedures to safely reduce aircraft spacing in the terminal area, enhance air traffic management (ATM) and reduce controller workload, improve low-visibility landing and surface operations, and to integrate aircraft and air traffic systems to address the problems described above. By the end of the decade, integrated ground and airborne technology will safely reduce spacing inefficiencies associated with single runway operations as well as the required spacing for independent, multiple runway operations conducted under instrument flight rules. Single runway operations are expected to increase by at least 12 to 15 percent under instrument weather conditions. Given the capabilities of future air traffic control automation and improved wake vortex knowledge, “dynamic spacing” between pairs of aircraft types in the landing sequence for a given airport runway system is possible and desirable for maximum safety, capacity and efficiency.

The goal of the **Advanced Air Transportation Technology** (AATT) project is developing technologies to enable the next generation of increases in capacity, flexibility and efficiency, while maintaining safety and not degrading the environment, of aircraft operations within the U. S. and global aviation system. In alignment with the national consensus for the operating paradigm of the future, called “free flight”, the technical objective is to provide human-centered, error-tolerant automation to assist in short- and intermediate-term decision-making among pilots, controllers and dispatchers to integrate block-to-block planning services. This will allow all airspace users to choose the best flight path for their own purposes within the constraints of safety and the needs of other users. Specific objectives include: (1) enabling “free flight” to the maximum possible degree to allow users to maximize business/customer impacts by making trade-offs between time and routing; (2) improving the effectiveness of high-density operations in regions on the ground and in the air where free flight will not be possible, and (3) enabling operation in a smooth and efficient manner across boundaries of free flight and capacity-constrained flight regions.

While the tiltrotor has been shown to be a viable military aircraft (V-22 Osprey), insufficient research has been undertaken on technologies critical to civil applications such as noise, terminal area operations, safety, passenger acceptance, weight reduction, and reliability. The **Civil Tiltrotor (CTR)** project focuses on noise reduction; cockpit technology for safe, efficient terminal area operations; and contingency power. To achieve acceptable levels of external noise in the terminal area, prop-rotor noise must be reduced by six decibels A-weighted (dBA) over current technology. Complex flight profiles involving steep approach angles and multi-segmented approach paths will be developed to provide an additional six dBA reduction. To enable these approaches to be safely flown under all weather conditions, integrated and automated control laws and displays will be developed.

SCHEDULE AND OUTPUTS

Terminal Area Productivity:

Transport system research vehicle (TSRV) ready to perform terminal area research.	Provide flight research capability for support of TAP technology development and demonstration.
Plan: September 1998 Actual: December 1998	Aircraft modifications and research systems installation completed. Flight demonstration revised to December 1998 due to unplanned technical difficulties.
Demonstrate Advanced Vortex Sensing System with transport of vortices and class-wise spacing Plan: September 1999	Conduct field evaluation of an initial demonstration of AVOSS technologies with transport of vortices and class-wise spacing features. Will demonstrate performance of vortex transport models for use by FAA to potentially reduce approach spacing standards.
Flight test full CTAS coordinated with FMS Plan: April 2000	Conduct field evaluation of Center-Terminal Radar Approach Control (TRACON) Automation System (CTAS) decision support tools operating in coordination with aircraft Flight Management System.
Complete demonstrations of all TAP-developed technologies and procedures Plan: September 2000	Complete all of the demonstrations for the TAP project. Demonstrate all TAP technologies in a realistic NAS environment achieving a 12 – 15 % increase in single runway throughput and proving the ability to apace aircraft closer than 3,400 feet on parallel runways while meeting all FAA safety criteria.

Advanced Air Transportation Technology:	
Complete definition of expanded operational evaluation for complex airspace and distributed air/ground traffic separation Plan: September 1999	Complete studies and down-select to recommended operational evaluations for both complex airspace and for distributed air/ground traffic separation.
Develop and demonstrate extended terminal area decision support tools for arrival, surface and departure operations Plan September 2000	Conduct field evaluations of individual decision support tools for management of arrival, surface and departure traffic.
Civil Tiltrotor:	
Flight database of low-noise operating procedures Plan: July 1999	Acquire in-flight database for low-noise operating procedures.
Isolated Rotor database for low-noise rotor concept Plan: December 1999	Acquire rotor database for low-noise rotor concepts and for code validation.
Full-span civil tiltrotor wind tunnel testing. Plan: September 1999 Revised: January 2000	Complete full-span, wind-tunnel testing of civil tiltrotor model to demonstrate low noise rotor concepts and acoustic code validation with wake and fuselage effects. Test delayed due to unavailability of wind tunnel due to technical problems

ACCOMPLISHMENTS AND PLANS

In FY 1998, the FAA selected three of the (CTAS) decision support tools developed by the **Advanced Air Transportation Technology** project for implementation as part of Free Flight Phase 1. The Collaborative Arrival Planning (CAP) tool was installed in the American Airlines Systems Operations Center at Fort Worth, TX. The first step in eventually accommodating a greater range of user preferences in sequencing and scheduling of arrival traffic in the Center and TRACON airspace was taken. The initial operational evaluation showed improved estimated time-of-arrival, reduced airline status calls to ATC, and assistance in preventing aircraft diversions. A piloted simulation to examine potential human performance issues of controllers and flight crews in the Free Flight environment was conducted with airline crews and air traffic controllers. This integrated ground/flight deck simulation provided new insights into human factors issues associated with self-separation, including workload, timing, and communication, for range of separation scenarios. In the **Terminal Area Productivity** project, the electronic moving map (EMM) display and HUD symbology study was completed. Sixteen airline crews completed 21 simulated landing-and-taxi-to-the-ramp trials at Chicago-O'Hare in NASA's Advanced Concepts Flight Simulator. Preliminary analysis show that the addition of the T-NASA displays (EMM and HUD) eliminated virtually all crew taxi errors. Taxi speeds were increased by 26% for day IMC crews, and 18% for the night VMC crews. Also all Aircraft Vortex Spacing System (AVOSS) subsystems were proven in initial deployment at Dallas Fort Worth. Early results indicate significant capacity gains possible if and when AVOSS is completed. For example, spacing reductions of up to 1 mile between certain pairs of aircraft may be achievable under frequently occurring weather conditions. The seventh comprehensive piloted simulation of the **Civil Tiltrotor** project completed the development of a comprehensive simulation database on control and display concepts. This latest simulation evaluated a new Flight Path Vector display format and terminal area guidance algorithms. These tests included several scenarios of adverse weather, changing air traffic, and engine failure.

During FY 1999, in the **Advanced Air Transportation Technology** project, the definition of an expanded operational evaluation of advanced air transportation technologies for application to complex airspace and for distributing tasks between flight crews and ground controllers for safe air to air separation will be completed. In the **Terminal Area Productivity** project, a flight test will be conducted to demonstrate the CTAS on the ground and advanced FMS in the flight vehicles utilizing data-link capabilities to facilitate information exchange between CTAS FMS. In the **Civil Tiltrotor** project, wind-tunnel testing of an isolated rotor model will acquire a database for low noise rotor concepts and acoustic code validation and a flight experiment will be conducted to obtain an acoustic/operations database for low-noise flight operating procedures.

During FY 2000, in the **Advanced Air Transportation Technology** project, field evaluations will be conducted to evaluate and demonstrate individual decision support tools for management of arrival, surface and departure traffic. Expect to demonstrate potential for 30% increase in throughput for extended terminal area. The **Terminal Area Productivity** project will be completed in FY2000 with the final demonstration of all developed technologies and procedures. Program expected to demonstrate potential for an increase of 12 to 15% in airport throughput. Specifically, a flight test will be conducted to demonstrate CTAS decision support tools on the ground and an advanced FMS on the aircraft utilizing data-link capabilities to facilitate information exchange between the two systems. In the **Civil Tiltrotor** project, wind -tunnel testing of a full-span tilt-rotor model will demonstrate low-noise rotor concepts and will validate acoustic codes with wake and fuselage effects.

BASIS OF FY 2000 FUNDING REQUIREMENT

AVIATION SAFETY PROGRAM

	FY 1998	FY 1999	FY 2000
	(Thousands of Dollars)		
Aviation Safety Program	0	0	60,000

PROGRAM GOALS

The world-wide commercial aviation major accident rate has been nearly constant over the past two decades. While the rate is very low (approximately one hull loss per 2 million departures), increasing traffic over the years has resulted in the absolute number of accidents also increasing. The world-wide demand for air travel is expected to increase even further over the coming two decades - more than doubling by 2017. Without an improvement in the accident rate, such a traffic volume would lead to 50 or more major accidents a year — a nearly weekly occurrence. Given the very visible, damaging, and tragic effects of even a single major accident, even approaching this number of accidents would clearly have an unacceptable impact upon the public's confidence in the aviation system, and impede the anticipated growth of the commercial air-travel market. The safety of the general aviation (GA) system is also critically important. The current GA accident rate is many times greater than that of scheduled commercial transport operations. With the GA market is also poised to grow significantly in future years, safety considerations must be removed as a barrier if this growth is also to be realized. Controlled Flight into Terrain (CFIT) and loss of control are the two largest commercial accident types, with weather, approach and landing, and on-board fire as additional significant categories. Human error is cited above all other issues as the prime contributing factor. For General Aviation, weather issues, CFIT, and loss of control also dominate the accident statistics.

In February 1997, to aggressively address these issues, President Clinton announced a national goal to reduce the fatal accident rate for aviation by 80% within ten years. This national aviation safety goal is an ambitious and clear challenge to the aviation community. NASA responded to the President's challenge with an immediate major program planning effort to define the appropriate research to be conducted by the Agency. Four industry- and government-wide workshops were conducted in early 1997 to define research needs. Four hundred persons from over one hundred industry, government, and academic organizations actively participated in setting the research investment strategies. This led to NASA's aviation safety initiative and a redirection of the Aeronautics Research and Technology Base in FY 1998 to immediately begin aviation safety research. The Aviation Safety Program (AvSP) is NASA's next step in responding to the challenge. The goal of AvSP is to develop and demonstrate technologies that contribute to a reduction in aviation accident and fatality rates by a factor of five by the year 2007 compared to the 1994-1996 average.

STRATEGY FOR ACHIEVING GOALS

The NASA AvSP approach for contributing to the national goal is to develop and demonstrate technologies and strategies to improve aviation safety by reducing both aircraft accident and fatality rates. Program planning gives high priority to those strategies that address factors determined to be the largest contributors to accident and fatality rates as well as those that address multiple classes of factors. Research and technology development will address accidents involving hazardous weather, controlled flight into terrain, human-error-caused accidents and incidents, and mechanical or software malfunctions. The safety program will emphasize not only accident rate reduction, but also a decrease in injuries and fatalities when accidents do occur. The program will also develop and integrate information technologies needed to build a safer aviation system--to support pilots and air traffic controllers--as well as provide information to assess situations and trends that might indicate unsafe conditions before they lead to accidents. The focus of each program element is the development of one or more prevention, intervention, or mitigation strategies aimed at one or more causal, contributory, or circumstantial factors associated with aviation accidents.

The AvSP will work as partners with the Federal Aviation Administration (FAA) in implementing the program and will maintain close coordination with the Department of Defense and other government agencies. Additionally, the program will work in concert with the full spectrum of commercial, rotorcraft, and general aviation industry manufacturers, suppliers, and operators in implementing the effort. Langley Research Center (LaRC) is the program's Lead Center and works closely with program personnel at Ames (ARC), Glenn (GRC), and Dryden (DFRC) Research Centers.

The AvSP programmatic and technical approach has been developed in close cooperation with the Federal Aviation Administration as well as the broad aviation community. The Aviation Safety Program Manager is a member of the Commercial Aviation Safety Team and the General Aviation Joint Steering Committee, the government/industry leadership groups developing and managing the overall National safety strategies. NASA aviation safety research and development efforts will therefore complement both FAA and industry activities as a coordinated overall effort.

The technology development and investment strategy for Aviation Safety Program is based upon a data-driven approach. Resources and technology efforts are focused on those accident categories and causes which that data show are most significant. Based upon analysis of National Transportation Safety Board Accident Statistics and other relevant aviation safety data, each technology project activity will have developed measures of projected accident rate impacts by the start of the AvSP in FY 2000. These metrics will be continuously tracked and updated throughout the program.

Success of technology development will be based on the demonstration of sufficient technology maturity to enable partners and customers to adopt and complete the technology application. This maturation process will be assessed as Technology Readiness Levels (TRL). In general, the AvSP will develop technologies to which demonstrates a technology through a system or subsystem model or prototype in a relevant environment.

Associated with each technology development effort will be on-going activities by NASA and the FAA to motivate and assist in the implementation of program outputs into the aviation community. NASA researchers will stay involved to help program "outputs" become "outcomes." This process will mean that NASA will work industry and FAA partners to progress technologies through implementation. This process will be assessed through an Implementation Readiness Level (IRL) scale complementing the TRL scale noted above.

As a partnering strategy aimed at securing participation from organizations motivated to bring advanced safety technologies to implementation, the program will emphasize cost-shared cooperative agreements requiring matching or greater funds from industry partners.

The Technical Program is comprised of six major projects: Aviation System Monitoring and Modeling (ASMM) project provides decision makers in air carriers, air traffic management, and other air services providers with unprecedented in-depth measures of the health, performance, and safety of the National Aviation System (NAS). Capitalizing on revolutionary advances in information technologies and digital communications, ASMM applications will enable definition of operational and safety baselines and trends and identification of developing conditions that could compromise aviation safety. ASMM output will also provide technology and procedure developers with the capability for reliable predictions of the system-wide effects of potential changes introduced into the aviation system. System technologies will first be implemented within specific organizations, but will be readily and subsequently expanded to national and world-wide applications.

The three-fold approach of ASMM is to (1) develop advanced information technology linkages, data structures, and tools to readily access information pertaining to all aspects of the NAS operation, (2) develop tools to identify, analyze and characterize both normal and non-normal operations and uncover previously unrecognized situations that may indicate changes to levels of safety, and (3) provide world-wide capabilities to obtain, access, and share relevant data on aviation operations among the aviation community.

System-Wide Accident Prevention (SWAP) project address aviation safety issues associated with human error and procedural non-compliance, which are broadly applicable throughout the aviation system. As human error is a factor in 60-80% of aviation accidents, generally reducing or mitigating the effect of human error will result in significant reductions in the aviation accident rate. SWAP will pursue research activities in three key areas identified from in-depth assessments as the highest priority applications: (1) Human Error Modeling, (2) Training, and (3) Maintenance Human Factors. Human Error Modeling efforts will target key aviation hazard issues (such as flight deck automation hazards, controlled flight into terrain, and others) to develop, test, and prove general design principles and operational improvements from a human-centered perspective. Training research efforts will target both training effectiveness improvements (training to performance levels over training to pass a test) as well specific training module developments for key safety issues such as flying in icing conditions. Maintenance Human Factors will make key investments in developing applications for procedural improvements and will as technologies for advanced displays and automation.

Single Aircraft Accident Prevention (SAAP) projects develop and support the implementation of safety technologies for in-flight applications. Based upon current accident data, the leading accident categories that SAAP will address are Controlled Flight Into Terrain (CFIT), Loss of Control in Flight, and Runway Incursion (RI) type accidents. Human factors issues and considerations cut across all of these categories and will be an integral part of the technology development process. Both commercial transport and general aviation vehicle classes are included. SAAP will pursue research activities in the following technology areas: (1) Health Management and Flight Critical Design Technologies, and (2) Control Upset Management. Health Management and Flight Critical Design technology developments will utilize advanced on-board measurement and diagnostic methodologies to monitor key flight systems for both hard failures and previously unrecognized trends leading to failures. Significant safety improvements and maintenance cost savings are expected. Control upset management technologies will target automated and pilot control techniques to prevent aircraft upsets resulting from systems failures or external inputs as well as techniques for recovering from unusual attitude conditions should an unavoidable upset occur.

Weather is a factor in approximately 30 % of aviation accidents. In addition, the majority of CFIT and GA “Loss Control” accidents result from visibility-induced crew errors, where better weather information or better pilot vision would have been a substantial mitigating factor. **Weather Accident Prevention** (WxAP) projects will develop and support the implementation of technologies to reduce the fatal accident rate induced by weather hazards. All aircraft types are to be considered. WxAP will pursue research activities in the following technology areas: (1) Aviation Weather Information Dissemination and Presentation and (2) Turbulence Detection and Mitigation. Aviation Weather Information Dissemination and Presentation technologies will bring implemented cockpit graphical weather display systems to early operational use. Ground-based, satellite, and in-flight weather information products, a digital communications infrastructure, and flight deck displays are to be developed and evaluated in commercial operation. Future growth of weather products and pilot decision aids will follow. Turbulence detection and mitigation technologies are aimed at eliminating the leading cause of in-flight injuries for the airlines. Improved forecasting, predictive sensing, and hazard characterization technologies are to be developed and tested in an integrated systems-based approach to turbulence avoidance.

Nearly all controlled flight into terrain commercial transport accidents and a significant percentage of general aviation accidents result from visibility-induced pilot errors. When terrain, obstacles, or (for low-experienced pilots) the horizon are not visible at night or in poor weather, simple mistakes (which would be readily apparent in clear daylight) can turn into major accidents. A potentially powerful approach to completely eliminate such consequences is to target this visibility-based problem with a vision-based solution. By developing precision navigation applications, high resolution terrain data bases, and graphical cockpit displays, **Synthetic Vision** technology development will provide commercial and general aviation pilots with clear out-the-window views regardless of the actual visibility conditions. In addition to the potentially very large safety improvements, which would result from such a revolutionary system, substantial operational benefits should also result from added all-weather aircraft capabilities. The Synthetic Vision project will focus on technologies and system applications of terrain displays, precision approach and landing guidance and displays, and low visibility surface operations. Close cooperation with the FAA for overall certification issue resolution, and the National Oceanic and Atmospheric Administration (NOAA) and the National Imagery and Mapping Agency (NIMA) for terrain data base development is planned. In addition, engaging airline, avionics, and airframe industry/government partnerships is planned to maintain a focus on actual system implementations.

Accident Mitigation (AM) projects will develop, enable, and promote the implementation of technology to increase the human survival rate in survivable accidents, and to prevent in-flight fires. To reach a goal of reducing fatalities, the number of survivors needs to be increased in accidents that are of the severity level where some, but not all, passengers survive. Fatalities are the result of impact factors, fire/smoke, or some combination of both. The overall approach in AM is to reduce the physical crash dynamics hazards, minimize fire effects in order to allow more time for evacuation, and reliably detect/suppress in-flight fires. AM technologies are targeted at all classes of aircraft.

SCHEDULE AND OUTPUTS

Aviation System Monitoring and Modeling:	
Apply Aircraft Performance Monitoring System (APMS) to Air Traffic Control (ATC) Plan: June 2000	Demonstrate application of APMS concepts & methodologies to ATC for performance monitoring
System-Wide Accident Prevention:	
CD-ROM Icing Training Module Plan: September 2000	Develop CD-ROM icing training module for GA and commuter pilots.
Simulation Database for Adverse Conditions and Loss of Control Plan: September 2000	Complete development of a preliminary simulation database, mathematical models and 6 degree-of-freedom vehicle simulations to characterize adverse conditions, failures, and loss of control
Weather Accident Prevention	
Initial Aviation Weather Information Network (AWIN) Concept Flight Evaluation Plan: September 2000	Flight Evaluation of initial national capability for digital data link and graphical display of weather information.
Synthetic Vision (SV):	
Flight Demonstration of Runway Incursion Prevention Technologies Plan: September 2000	Concept demonstration of integration of air traffic control runway incursion information onto aircraft flight deck displays.

Accomplishments and Plans

FY 2000: $60.0 million

In FY 2000, the Weather Accident Prevention project will complete flight evaluation of an initial national capability for digital data link and graphical display weather information in an aircraft cockpit. This will be an assessment of a cockpit “weather channel” concept for national and worldwide commercial airline and general aviation benefit. Selections of concepts for continued development will be conducted for clear air turbulence detection systems. The System-Wide Accident Prevention project will develop and demonstrate an icing training module on CD-ROM for general aviation and commuter pilots. This will enable the broad dissemination of critical weather safety information to the national aviation community. Software application field tests will begin for maintenance human factors risk and task analyses. The Single Aircraft Accident Prevention project will develop an initial simulation database, mathematical models, and six degree-of-freedom vehicle simulations to characterize adverse conditions, system failures, and loss of control mitigation techniques. Synthetic Vision flight demonstration tests of FAA and NASA runway incursion technologies integrated onto an aircraft flight deck will be conducted at a major U.S. airport. These tests will provide technical and operational system performance assessments of the integration of airport surface databases and runway incursion warning systems into current technology cockpits. The Aviation System Monitoring and Modeling project will demonstrate the application of Aircraft Performance Measurement System concepts and methodologies to Air Traffic Control systems for performance monitoring. This work will take successful aircraft-based monitoring technologies and apply them to the broader context of the national airspace system risk identification and performance improvements. Airline evaluations and operational use of aircraft performance measuring software and analysis tools will be conducted. In the Accident Mitigation projects area, on-board inert gas and oxygen generation system concepts for fire prevention and emergency use will be defined and structural crashworthiness design analysis prediction codes development selections will be conducted.

BASIS OF FY 2000 FUNDING REQUIREMENT

ULTRA EFFICIENT ENGINE TECHNOLOGY

	FY 1998	FY 1999	FY 2000
		(Thousands of Dollars)	
Ultra-efficient engine technology			50,000

PROGRAM GOALS

NASA's role in civil aeronautics is to develop high risk, high payoff technologies to meet critical national aviation challenges. Currently, a high priority national challenge is to ensure U.S. leadership in aviation in the face of growing air traffic volume, new safety requirements, and increasingly stringent noise and emissions standards. NASA's role in aeronautics is also to support the Department of Defense (DoD) in maintaining superior defense capability. Propulsion has led the way for new generations of aircraft with breakthroughs in performance, reliability, and environmental compatibility. A prime example of NASA's contribution to technological advances in propulsion is the high bypass turbofan. This engine enabled the economic success of wide-body transport aircraft and achievement of new levels of fuel efficiency and dramatically reduced noise as compared to the earlier generation of jet aircraft. The attainment of Aero-Space Technology Enterprise goals requires comprehensive propulsion technology research and development spanning a broad range of aircraft applications from subsonic through hypersonic. The timing is right to invest in breakthrough technologies for a new breed of radically improved propulsion systems to power a new generation of aircraft required in the increasingly constrained airspace system.

NASA has a successful history of leading the development of aggressive high payoff technology in high-risk areas, ensuring a proactive approach is taken to developing technology that will both be required for meeting anticipated future requirements, and for providing the technical basis to guide policy by determining feasible technical limits. The Ultra Efficient Engine Technology Program addresses the most critical propulsion issues facing the Nation in the new millennium: performance and efficiency. In order to sustain the desirable forecasted growth of this important industry, these issues must be addressed without dampening this growth and therefore must improve performance and efficiency without incurring environmental penalties. Additionally, it is important to sustain the high reliability and safe operation without impacting the economics of operations. These propulsion technologies will also be of significant benefit to military engines where performance improvement is the principal goal driving DoD propulsion development for future military aircraft.

STRATEGY FOR ACHIEVING GOALS

The Ultra Efficient Engine Technology Program is planned and designed to develop high-payoff, high-risk technologies to enable the next breakthroughs in propulsion systems to spawn a new generation of high performance, operationally efficient and economical, reliable and environmentally compatible U.S. aircraft. The breakthrough technologies are focused on propulsion component and high temperature engine materials development and demonstrations enabling future commercial and military propulsion systems which are greatly simplified, achieve higher performance, and have potential for much reduced environmental impact with a broad range of aircraft application. Four investment areas form the basis for the technical approach: materials & structures, to address the barrier technologies and expand the knowledge databases associated with high temperature; combustion, to develop the technology necessary to address efficient high temperature, high pressure. High performance systems; turbomachinery, to develop highly coupled/loaded engine component technologies incorporating breakthrough features with potential for integrated propulsion demonstrations; and integration & assessments, to understand the complexity of interplay among technology benefit, tradeoff and impact.

NASA's investments will develop the underlying understandings and design information to mitigate both the risk and cost of applying the technology-based solutions. The success of this program is dependent on partnerships to enable transfer of the resulting technology. As a result, a key element of this program is to develop high-payoff technologies, in cooperation with DoD, the Federal Aviation Administration (FAA), the U.S. aeronautics industry and academia, to benefit the public.

SCHEDULE AND OUTPUTS

Combustion: Combustion research facility upgrade completed	Make operational the second leg of the Advanced Subsonic Combustion Rig, a unique world class facility, which is required for testing of combustor configurations (flame tube and sector) required for future ultra high pressure ratio engine cycles.
Plan: September 2000	
Combustion: Select 70% emissions reduction concept for full combustor evaluation	Demonstrate in a laboratory combustion experiment (flametube) an advanced turbine-engine combustor concept that will achieve up to a 70% reduction of oxides of nitrogen (NOx) emissions based on 1996 ICAO standard.
Plan: September 2000	
Materials & Structures: Complete high temperature engine material down-select	Complete selection of those materials systems that will be developed for complex geometry's such as cooled turbine vanes with thermal barrier coating and capable of sustained 3100°F turbine rotor inlet temperatures
Plan: September 2000	
Turbomachinery: Validation of aero-performance prediction code	Complete single stage cascade tests of turbine configurations which incorporate flow control to improve aerodynamic performance and use flow physics data set acquired to validate NASA's average passage (APNASA) computer code
Plan: September 2000	

ACCOMPLISHMENTS AND PLANS

This is a new program beginning in FY 2000

In **Combustion**, the world class high pressure ratio combustion research facility upgrade will be completed to allow parallel operation of basic combustion research for combustion diagnostics and physics based model calibration and for sector testing to validate advanced high performance combustor designs. The facility leg already in place will be conducting final flame tube and initial sector experiments on high pressure combustor concepts in the process of identifying solutions and combustor designs to achieve dramatic reductions in NO_X production.

In **Materials & Structures**, the selection of those materials systems that will be developed to the subcomponent, complex part scale in this program will be completed. The suite of materials from which this selection will be made is the suite is focused only on those critical to enable the high performance 21st Century propulsion systems. An initial high priority activity will be to move a preliminary high temperature material and coating from the laboratory to realistic scale parts for evaluation and analysis, including the thermal barrier coating. This will enable the early demonstration of a significant increase in engine temperature with commercial life. One critical material system, ceramic matrix composites, is essential to both future commercial and military engines. This program is the only national effort in CMCs and is a key technology where DoD is reliant on NASA. Work on high temperature, lightweight organic matrix composites will also be initiated

In **Turbomachinery**, a set of single stage cascade tests of turbine configurations will be completed which incorporate flow control enabling unprecedented levels of aerodynamic performance and use flow physics data set acquired to validate APNASA code. Initial research on single stage aspirated compression components will be accomplished with the target for proof of concept test for the following year.

In **Integration & Assessment**, studies will be performed to quantify key program metrics and minimum success criteria and to guide program investments, and to define viable tradeoffs of technologies with interdependent system benefits. Of particular interest is defining the environmental benefits, tradeoffs, and impacts.